

Supplementary Matter

vol.-2

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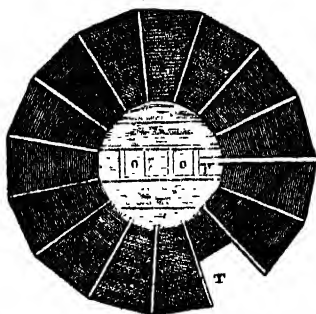
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in every respect similar to that produced by the distillation of wood in close vessels.

Such are the improvements which have been effected in operating with the ordinary meiler, having no regard to the perfection of the process by turning to profit all the products afforded by the wood; but, from the number of these, and their utility in the arts, their waste could not be long permitted, especially when their value became known. To submit the wood to distillation in close vessels, however, would involve a considerable outlay in costly apparatus, which at the same time would fail to furnish a quantity adequate to the requirements of the trades which consume it, and hence more simple, as well as more effectual methods were a desideratum. The conditions required were, to a great degree, fulfilled by the processes proposed by FOUCAUD, BAILLET, and SCHWARTZ, but others have been suggested and acted upon.

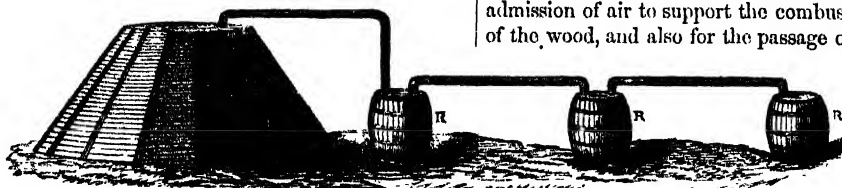
FOUCAUD's method, which is the simplest of these, is founded on the principle of sheds; all the other details being much the same as in the common *pile* process. A covering is provided, which, while it affords all the advantages derived by the use of sheds, adds

Fig. 27.



meiler being ignited passes out; and after this the condensable products are drawn off through the third opening by a pipe bent at right angles, and conducted into the first of a series of condensers, R R R. This arrangement is shown in elevation in Fig. 28, where

Fig. 28.



the decomposition of the contents. It is constructed by digging a circular cavity in the earth of any convenient depth; or, where this cannot be done, building a mould wall round the space corresponding to the size of the furnace. When sunk in the ground, holes are made perpendicular to the base, and at a distance of a foot from the facing of the wall of the cavity; they are made to open inwards at the base. In the other form, the perforations are fixed at the base to open inwards in the same way. Fig. 29 represents this kind of carbonizer, half in plan and half in elevation, and Fig.

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the means of collecting the volatile products in suitable condensers; and to render it more efficient, it is so made as to be simple and economical—the diameter of the base being thirty feet, at the top ten feet, and the height eight or nine feet. To form this shed, frames twelve feet long, three broad at one end, and one foot at the other, are constructed of bars of wood two inches square. Upon these, stout twigs in the form of wicker-work are woven; wooden holders are attached to each frame, by which, and the use of an iron or wooden pin, they may be joined together. Before putting them up, it is customary to coat them with a well-tempered

Fig. 25.

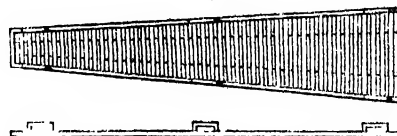


Fig. 26.

loam, with which some chopped grass is mixed. Fig. 25 shows one of these frames, and Fig. 26 one side with the holders appended.

When a number of these are adjusted together, they form a frustrum of a cone, the top of which is closed with a flat lid, ten feet in diameter, and made of boards well connected. In the centre are three openings or trap-doors, O O R, as seen in Fig. 27. Through two of these, O O, the first smoke which is evolved on the

may be seen the opening, T, by which the workmen can enter or go out at pleasure. When the object is to collect the acetic acid only, some have proposed coating the mould with a species of mortar made with quicklime; the acid unites with this base, and forms acetate of lime, which may be treated as indicated under ACETIC ACID.

BAILLET's form of carbonizer, reproduced with various improvements in the apparatus of M. LA CHAUBEAUS-SIÈRE, consists of a cylindrical chamber, covered with a plate of cast-iron, and furnished with orifices, for the admission of air to support the combustion of a portion of the wood, and also for the passage of the products of

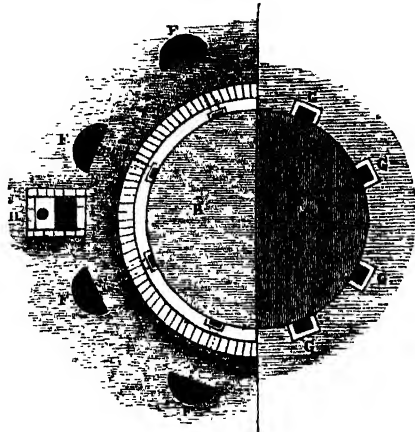
30 a section of the same. In the first of these, A denotes half the plan at the level of the base, and B the other elevated portion under a vertical view. The same are seen in section, where C indicates the half section over the chimney, and D the half over the air-channels.

The bottom of the furnace, E, is constructed of refractory clay, well beaten, or of bricks; so also are the side openings, G, of the air-channels in the bottom. FF indicate the mouths of these holes, H is the brick-chest or pipe for conducting the smoke, and I the casing of

F

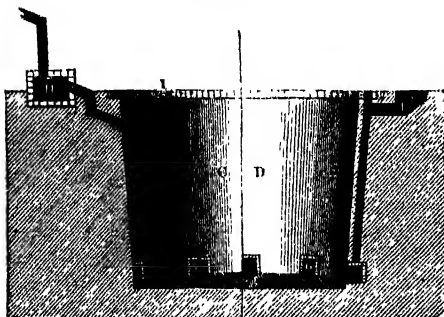
the same material upon which the verge of the lid rests. This most important part of the furnace is constructed of wrought-iron plates, bound by clamps or

Fig. 29.



hoops of sheet-iron. Its form is a segment of a sphere, its diameter is ten feet six inches, being six inches wider than the pit, so that it will rest three inches over

Fig. 30.



the edge of the wall. It ought to be sufficiently solid to bear the weight of a man without being injured. A perforation, *a*, Fig. 31, is made in the centre; this opening, which is nine inches in diameter, and closed by a movable plug of iron, serves as a vent for inducing

Fig. 31.



the ignition of the wood, as well as for introducing red-hot coals for that purpose. There are four other openings, *b b*, equidistant from each other, and six inches from the rim. The diameters of these are only four inches, and they are intended as draught-holes for the escape of the first heavy vapors that are given off when combustion sets in. In diameter the furnace is about ten feet at the base, being a little more at the top, and it is nine to nine and a half feet in depth. About six inches thick of solid flooring, composed of refractory clay, is laid on the bottom, bringing this up to the level of the inlets. It should be well beaten, in order that it may the better resist the heat, as should likewise be that of the walls of the furnace. The air-

holes are generally about two to two and a half inches in diameter, though openings of a less calibre would be sufficient; but by placing a tile upon the orifice, the volume of air may be reduced at pleasure.

The outlet through which the volatile products pass is introduced at about nine inches below the ledge of the furnace; it is nine inches in diameter, and inclines towards the body from the further end, which abuts in a rectangular box, eighteen inches in length, twelve in breadth, and fifteen in height. During the distillation, tar and portions of the acid condense in the box, the walls of which are made of brick, the cover being a movable plate of iron; and when nearly filled, or in such a state as that it would obstruct the passage of the vapors, the excess is drawn off by a stopcock in the side near the bottom. A cast or wrought iron pipe is fixed vertically in the lid of the box, and at the height of about four feet it is bent horizontally, or slightly depressed; the horizontal part is about fifteen feet in length, so that the contents may be cooled during their passage, and prevented from spontaneously igniting. The far end of this pipe discharges itself into a wooden sluice or covered trough, which conducts the products into suitable condensers. Before putting the furnace in operation, it must be well dried by lighting some brushwood, and keeping up the heat till the bottom and sides are thoroughly baked. The charging is commenced by fixing a round stake four inches in diameter in the bottom, and of the same height as the furnace. Around this, some charcoal is placed to keep it upright, and then logs of wood are arranged horizontally, radiating towards the circumference and between the air-holes, observing that the ends reach neither to the central stake nor to the wall of the furnace. The spaces unoccupied between the radii, form so many flues from the draught-holes to the centre. Another layer of logs is laid transversely upon these spaces, and close to each other, thus leaving as few vacancies as possible. Other layers are placed upon this successively till the furnace is filled, and all the spaces round at the circumference are charged, either by alternating the logs, or by employing smaller wood for this purpose.

The next step is to withdraw the central shaft, and to fix the cap in its place; the latter operation is facilitated by the use of two iron levers and wooden rollers twelve feet in length, which pass over the furnace and rest on the ground at each end. All the openings in this cover are left free, and the remainder is coated with a layer of loose dry earth or sand, two inches thick, in order to cause it to be as retentive of the heat as possible. The draught-holes round the circular wall of the furnace are likewise opened. At this stage, some red-hot embers are poured down the central vent-hole through a kind of funnel, and these falling through the space previously occupied by the stake, which acts as a kind of chimney, come in contact with the combustible material at the bottom, which is soon ignited. For the purpose of diffusing the flame over the contents of the furnace, the central orifice is closed as soon as the fire has acquired sufficient strength. After the bluish smoke which escapes from the charcoal changes to a whitish shade, the draught-

holes in the cover are partly closed, as are also those leading to the base of the furnace; and when the combustion is thought sufficiently brisk, the openings in the cover are entirely stopped, and the vapors allowed to pass off to the condenser. Sometimes the draught produced by the chimney at the end of the condenser is not powerful enough to cause a rapid transmission of the gases and other volatile products from the furnace, in which case the fire is apt to flag or become extinguished. This state of things is detected by the vapors being driven back in the outlets through which they ought to proceed. To remedy the evil, the air-holes at the top of the cover might be opened and a portion of the products allowed to escape, rather than suffer the fire to go out; but the best contrivance is to have a second opening at the top of the furnace, to which pipes may be appended for conducting the gases off to the condenser, but capable of being closed when not required.

The charring generally requires from sixty to eighty hours to produce a good quality of charcoal, but the period is, of course, variable. The attendant examines the state of the interior by thrusting a pole into the furnace through the central opening, and observing if the reduction in the bulk of the mass be equal in all parts. If this be not the case, the draught-hole is opened near that part where the subsidence is least, as also the air-hole opposite to it at the base, and in a very short time the equilibrium is re-established. As soon as the charring is thought to be completed, either by examination with the pole or from the appearance of the smoke which may be evolved, all the air-channels and draught-holes in the cover are opened, with the exception of the central one; a brisker combustion ensues, and some hydrogen which has been hitherto retained is given off. In consequence of this, the charcoal changes from a reddish-brown to a black color, and is so far rendered more marketable. Immediately on the surface of the charcoal becoming incandescent—a state which may be observed by looking through the orifices in the cover—all the openings by which air entered or vapors escaped are carefully closed; the temporary covering on the cap is removed, and replaced by a coating of thin loam. Thus secured, the whole is left from seventy to eighty hours to cool. The furnace is then uncovered for the purpose of removing the charge of charcoal.

It will be observed that the contents at this period possess no more than half the bulk of the wood originally introduced; this reduction arises not from the actual contraction of the matter in charring to that extent, but from the filling up of the interstices by the burned material.

A workman now descends into the furnace and empties it of its charcoal, by taking the pieces up one by one, using as much precaution as possible that they are not broken. The smaller fragments and charcoal dust are removed with a shovel, and collected in a heap together. Should the contents not be thoroughly cooled, the workman employs an iron tool which protects his hands from the heat. Any live or half-burned charcoal which may be present is assorted by itself, then spread out and occasionally raked about, by which it

becomes extinguished of its own accord, and without the use of water; it would be well, however, to have some at hand, in which to immerse any pieces that may be detected burning, which is known by the appearance of white spots. When the furnace is emptied, it is re-charged in the manner already described, and all the operations are repeated in the same manner, and proceeded with as previously detailed.

Five active workmen have been found sufficient to superintend successfully eight such furnaces, working without interruption, and producing on an average twenty per cent. of charcoal throughout the year. The following statement of the work of these furnaces gives a fair average of their annual produce:—

	Tons	Cwt.	Qrs	Lbs	
5000 stères of oak, weighing	123	0	3	16	produced
16,000 hectolitres of charcoal, weighing.....	24	12	0	21	
Impure acetic acid,.....	22	0	0	17	
Yielding upon distillation a purified article, marking 12°					
Twaddell, weighing from	12	15	3	21	
To	13	15	2	14	

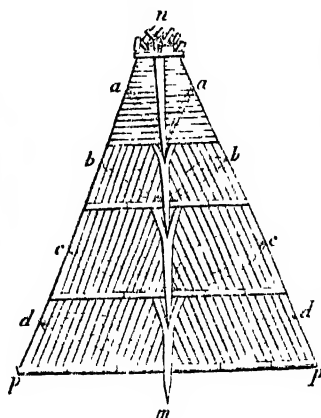
The outlay in the construction of each furnace is said to be four hundred and fifty francs, or about eighteen pounds fifteen shillings, of which sum sixteen pounds thirteen shillings are paid for the cap, the balance being ample for constructing the body of the furnace. The condensing apparatus is not included in this statement.

On reference to the article ACETIC ACID, Vol. I. p. 18, the apparatus of SCHWARTZ will be found fully described; and, therefore, any further description of it will be here unnecessary; but something may be added as to its efficiency compared with the others. In localities where there is considerable demand for charcoal, such as in some parts of France and Sweden, where it is largely consumed in smelting operations, the apparatus of SCHWARTZ is better adapted to yield the requisite supply than LA CHABEAUSSIÈRE'S; it likewise answers better for coniferous woods, as the large amount of tar which these yield is most effectually recovered by it. On the other hand, it must be admitted that the wood is more completely charred in the latter, and the time occupied in proportion to the bulk is much shorter; that the cost of SCHWARTZ'S apparatus is much greater, and that it does not admit of removal like LA CHABEAUSSIÈRE'S, except under an outlay as great as the original cost of erection, namely, from eighty to ninety pounds. The advantage of using either of these forms depends greatly upon the facility with which the wood may be conveyed to the melter, as it is evident that, if the distance were great, the cost and difficulties of the carriage of wood over that of the charcoal would more than balance the value of the products of the distillation, and, in fact, of the greater yield of charcoal. In this case, the first method of carbonizing, in large melters, enclosed in easily movable sheds, will claim a preference to the other two; but sometimes, when the piles are required to be very large, the removal of these becomes more difficult and troublesome; so that their advantages are considered inadequate to the labor, and they are consequently dispensed with. It is evident, therefore, as DUMAS remarks, that in such districts all

the improvements to be made in the manufacture of charcoal must turn upon the better working of the meiler or pile, as being the most applicable; and hence, the first thing to be aimed at is to render this more independent of the cares of the workmen. Upon this, the difference between the pile system and that of distilling in close vessels turns; for, by the former, the most skilful practitioner may be baffled by circumstances peculiar to the operation; whilst, in the latter, the smallest amount of hand labor will always serve to prepare the charcoal, and in the largest quantity.

It is clear that the first consideration on the part of the burner of the pile is the lighting of the fire, so as to spread it over the largest extent of surface in the shortest possible time, and with the admission of as little air as possible. This is usually done by igniting the mass at the base, establishing a draught at the same time from the exterior and through the centre, as seen in Fig. 32, at *p m a*, till the upper parts of the pile are on the point of entering into incandescence. By closing the chimney, *n*, and opening vents at the points, *a a*, around the mound, a draught will be formed through *p m a*. These perforations will in turn be

Fig. 32.



closed, and new ones opened in succession; and as the carbonization advances in *b c* and *d*, care must be taken to bring the force of the combustion in the direction of *p m b*, *p m c*, *et cetera*, so as to char the whole in zones proceeding from the axis to the circumference, and then downwards towards the base. Such is the course

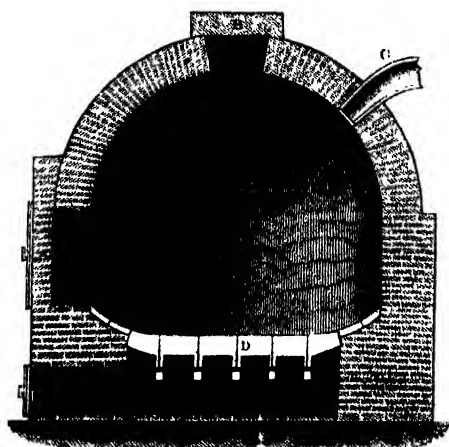
which is deemed the most favorable for the charring; but it is evident that this does not include all that is deserving of the operator's attention. An object, indeed, of primary consideration, is to render as much as possible of the caloric disengaged in the process available for decomposing the molecular arrangement of the matter of the wood. Could this end be fully attained, it is evident that the whole of the carbonaceous matter might be obtained in the form of charcoal. How far this is from being accomplished in the meiler system, those engaged in the business are best aware; as likewise how great a loss the slightest variation of temperature inflicts upon them. This regulation of the heat is, however, a problem, the solution of which would involve the removal of serious difficulties—a fact which will be readily admitted when the amount of water to be discharged as steam, the volume of gases liberated, and of air passing through the pile, are considered.

A method adopted in Sweden, which seems to be an improvement on the common plan, is to conduct

the draught downwards instead of in the ordinary way; and if the pile were constructed upon a base sloped from the centre to the exterior, this would allow of the draining of the tar, acetic acid, water, *et cetera*, into a suitable vessel. Pipes might be disposed through it, so as to conduct the draught from the vertex to the base of the cone, and all converging into a tank, where the vapors would be condensed as far as possible, the remainder passing out through a flue into a chimney of sufficient height to generate a draught powerful enough to carry on the combustion. By this course all the heat would be utilized, and the moisture disengaged would be prevented from passing through the ignited wood—a circumstance which causes considerable reduction of the charcoal left.

Another species of charring is that in which the heat is exterior to the wood which is to be carbonized, and is produced in an adjoining fire. Of this description of carbonizers is that represented in Fig. 33, a construction of brickwork, having apertures suited to the convenience of the workmen for charging and withdrawing the products. Of these, *A* shows the orifice through which the wood is introduced till it rises as high as this opening, after which it is closed, and the remainder of the interior charged through the superior aperture, *B*, and the orifice for the passage of the products of distillation is through the pipe, *C*. The fire which serves

Fig. 33.



to bring the contents to the point of decomposition is made on the grate, *D*, and the air which is to maintain its combustion enters by the ashpit, and is regulated by a door, *E*. When the kiln is charged, the apertures, *A* and *B*, are blocked up with bricks, or closely fitting lids. As soon as the walls have acquired so much heat as will be necessary to complete the charring, the communication with the air is cut off by closing the door, *E*. In carbonizing in this manner, the charring is more regularly effected, although the supervision of the attendant cannot be so well exerted as when the ordinary meiler is resorted to; in the latter, however, the influence of the weather can scarcely be controlled, however watchful the workman may be—a condition effected by the walls of the kiln, and hence its superiority.

Differing from the kilns of this description, but still

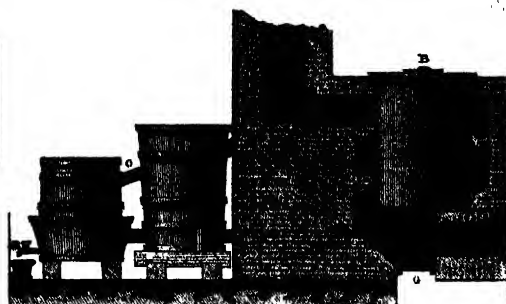
less advantageous in point of execution, are those kinds of carbonizers which char the wood without allowing the products of the combustion to come into contact with the materials to be decomposed. They possess an advantage over others, inasmuch as all the volatile products are recovered in the condenser, without anything being lost from a combustion taking place in contact with them. This advantage is partly neutralized by the large amount of fuel which is required to bring their contents to the proper working temperature, and the necessarily small volume which must be operated upon, owing to the non-conducting qualities of wood and charcoal. No less than a quarter of the product in charcoal is consumed for this purpose, even when the combustible gases which pass through the condenser unarrested are economised in the grate.

The close distillatory apparatus or retorts are the most eligible for the decomposition of pine wood, and such as contain a large amount of resins; and though, at a distance from the site where the wood is felled, they are generally composed of iron, yet near the locality they are sometimes constructed of well-tempered clay. Those known as tar-retorts are composed of two hollow cylinders, one within the other, and differing six or eight inches in diameter. The inner of these receives the wood, and is a little longer than the outer one. The space between them is appropriated to the fire, which is maintained by a current of air rushing in through apertures in the outer walls. A funnel shape is given to the base of the retort, and this is made to terminate in a pipe which traverses the outer cylinder, and abuts in a tar cistern where the products of distillation collect. By means of an aperture at the top of the inner cylinder the wood is introduced, and after the charging is performed, and all the outlets closed with the exception of those at the base, the fire is lighted in the intervening space between the outer cylinder and the retort, and the heat continued as long as volatile matters pass over to the receiver. When these cease, or sooner, provided the walls are sufficiently hot to finish the distillation, the fire is extinguished, and the apparatus allowed to cool.

A very good form of retort for the distillation of wood and the production of tar and charcoal, is that shown in Fig. 34 annexed. The body, A, of the retort is of cast-iron, imbedded in masonry or brickwork, so that the flue from the grate courses spirally to the top, where it turns off to the chimney. In the upper part of this case is a movable cover, B, through which the wood is introduced, and by which the charcoal is removed when the charring is finished. An outlet is made at the top under the rim, to which a pipe, C, is fixed that communicates with a large condensing vessel, D, covered at the top; this is connected with another, E, wherein all the condensable matters which escape from the first are arrested

and conducted to a recipient by the pipe and stopcock, O, whilst the non-condensable gases are reconducted by a pipe, F F, over the grate of the furnace, G, to be burned,

Fig. 34



and thus economise the fuel. The fire is made of taggots and brushwood, and is maintained till gases and vapors are abundantly evolved, at which stage a stopcock in the pipe, F F, is opened, and the inflammable products of the distillation are allowed to flow in over the fire, where, in burning, they produce as much heat, with a little addition of fuel, as will char the remainder of the contents. After the condensable matters cease to flow over, this tap is shut, and the retort is left to cool for a period of sixteen to twenty hours.

Such are the principal methods resorted to for the manufacture of charcoal from wood for the requirements of the smelter, the powder-maker, and others. It is evident, from the nature of the several processes, that considerable difference must necessarily exist between the charcoals produced, as well in their intrinsic value as in their physical appearance. This partly depends on the species of wood employed; but all the difference is not to be attributed to this circumstance. The study of charcoal, with a view to its application in the works where it is chiefly consumed on the Continent, has led to a modification of the usual mode of charring, by which a larger volumetric yield has been insured, answering all the purposes required. This product is designated *torrefied wood*, or *red charcoal*, from its reddish-brown appearance. BERTHIER was the first to call attention to this variety; but lately SAUVAGE conducted some experiments, from which he deduces that the amount of combustible matter obtained by the charring of wood does not increase after exposing the material to a suitable heat during a stated period, but that, on the contrary, a loss is sustained in the quantity. He limits the proper period to five hours and a half. The results of his experiments are transcribed in the annexed table, which shows the loss sustained in weight, and the volume at the intervals mentioned:—

100 lbs Wood charred for	3 hours	4 hours	5 hours	5½ hours	6½ hours	Mound Charcoal
Weighed 100 cubic feet by a similar treatment measured	65·4 pounds. 86 C.F.	53 pounds. 76 C.F.	47 pounds. 58 C.F.	41·5 pounds. 55 C.F.	39·1 pounds. 52 C.F.	17·2 pounds. 33 C.F.

cent. of the wood taken, whilst the produce of the kilns in the same quarters has been shown to be only a mean of about twenty-six per cent.; and this, when the quantity consumed in the operation is deducted, leaves only about twenty-two per cent., or rather less than that afforded by the ordinary process. It must be remarked, however, that the milder yield was in these cases an exception to their general produce, which is found much lower than the numbers so given, even when thick wood is operated upon; and the proportion is much further decreased when small wood is charred in them. It is a well-known fact, however, that none of the methods give, in the form of charcoal, more than two-fifths of the real amount of carbon in the dry wood. According to EBELMEN, this loss is occasioned not entirely by the products of the distillation carrying off portions of it in combination, but by the direct combustion of the charcoal in an incandescent state, caused incidentally by the oxygen of the air passing through it, and converting it into carbonic acid and carbonic oxide. This he proved by the comparative analysis of the vapors from the temporary chimneys in the milder, and of those developed in close vessels, where contact of the fire was entirely excluded. Of course, if the portion of carbonic acid which must necessarily be generated is permitted to traverse the incandescent charcoal, it will suffer decomposition at that temperature, and as much more carbon as it contained will be assimilated and lost to the charcoal-maker, the whole passing off in the form of carbonic oxide. The charcoal-burner's efforts should be directed to prevent this, by conducting the air which enters the milder over the uncarbonized wood; and after it passes that part of the heap where combustion is active, withdrawing it by means of the temporary openings in the cover, over the portion yet undecomposed, so as to be out of the reach of the made charcoal. It is almost impossible to effect this thoroughly, but the efforts made with that view by those engaged in the business show that its importance is appreciated, and doubtless a remedy will soon be found which will render the process more effectual than it is at present.

QUALITY OF THE CHARCOAL.—A few considerations may now be submitted with reference to the quality of the charcoal. Independently of the fact of the densest being the best, it happens that during the making it may be deteriorated, either by imperfect charring, or by pushing the process beyond the proper limits. In the former case the product is not good, on account of the gaseous elements which it retains, and which being disengaged in its subsequent application as fuel, render it less efficient for producing a high temperature; in the latter case it becomes so brittle as to be incapable of being handled without falling to powder: and the same crumbling occurs in the smelting furnace, where it is more injurious.

Good charcoal is very dark, possesses a bright lustre and somewhat conchoidal fracture; it resists gradual pressure to a considerable extent, and produces a sharp sonorous sound when allowed to fall upon a hard body. It should burn when ignited without either flame or smoke, and when handled no stain ought to remain. Although in bulk it floats in water,

owing to the arrangement of the particles, its specific gravity, when ground so as to destroy its porosity, is much higher than that of water. In addition to the carbon of which it chiefly consists, a certain amount of oxygen, hydrogen, and other gases is found in it, together with the mineral matter of the wood. The greater or less proportion of the former affects its calorific power, and renders it more or less eligible for certain uses in the arts.

The following analyses of two samples of charcoal prepared by the milder system, show the quantity of the different ingredients remaining, even after the charring has been carried to its utmost limits:—

	Centesimally represented.	
	Charcoal from Young Oak	Charcoal from the Aspen.
Carbon,	87.68	87.22
Hydrogen,	2.83	3.20
Oxygen,	6.43	8.72
Ash,	3.06	0.86
	100.00	100.00
Loss by distillation,	13.02	17.07

Red charcoal retains a somewhat larger quantity of the above gases, than the product of the milder or the close retort. The following table embodies the results of M. VIOLETTE's analyses of the charcoal prepared by the action of superheated steam, according to his process:—

Species of Charcoal.	Elementary Constitution Centesimally Represented.			
	Carbon	Hydrogen.	Oxygen, Nitrogen, and Loss	Ash
Furze,	76.620	4.108	17.975	1.288
Iron wood,	72.564	4.527	12.510	0.399
Cork,	72.362	8.528	19.110	..
Juniper,	71.433	5.073	23.321	0.170
Wild pine-tree,	71.358	5.948	22.194	0.500
Hawthorn,	70.793	4.413	23.419	1.345
Palm-tree,	70.724	4.552	23.494	1.230
Ash,	70.395	4.539	24.374	0.692
Maple,	70.069	4.613	24.892	0.425
Cherry-tree,	70.028	3.928	25.289	0.755
Lime-tree,	69.829	5.452	23.024	1.695
Yew,	69.620	5.864	24.212	0.304
Sycamore—maple,	69.229	4.402	25.133	1.236
Medlar,	69.209	4.613	25.261	0.887
Chestnut-tree,	69.127	4.326	27.126	0.421
Willow,	68.900	5.133	24.634	1.333
Yoke-elm,	68.835	4.142	26.382	0.641
Poplar—trunk,	68.741	4.866	25.540	0.853
Coco-tree,	68.268	4.053	23.984	3.695
Hollyoak,	68.521	4.741	25.891	0.847
Aspen,	68.169	5.512	25.730	0.589
Ebony,	68.047	3.868	28.380	0.205
Oak,	67.421	4.099	28.480	0.200
Poplar—root,	67.020	5.217	26.675	1.088
Elm,	66.862	4.669	28.181	0.288
Plum tree,	66.118	5.756	27.530	0.596
Pear-tree,	65.924	5.310	28.244	0.522
Hemp-stalks,	62.127	4.976	31.501	1.396
Wheat-straw,	61.090	4.365	34.786	0.759
Leaves—poplar-tree,	52.514	4.819	41.289	1.388

In this table considerable difference in the yield of carbon is apparent; but as the samples were prepared by the application of the same temperature, it is evident that the inequality must be owing to a difference in the principles contained in them, and to the greater or less difficulty with which they are decomposed. It must be remembered, however, that the woods them-

selves do not contain the same amount of carbon. Were the water and ligneous matter the same in all, probably the approximation of the results of analysis would be closer. The quantity of inorganic salts in the various samples is very small, much less so than one might suppose, considering that wood containing about twenty per cent. of moisture gives from one-third to one per cent., all of which is retained in the charcoal produced from it, generally amounting to about twenty per cent. The following results obtained by WINKLER are, therefore, more in accordance with what might be expected:—

	Ash Centesimally.
Lime-wood charcoal,	3.55
Maple,	2.27
Ash,	2.27
Elm,	2.17
Willow,	1.50
Fir,	1.44
Pine,	1.38
Poplar,	1.30
Beech,	1.25
Scotch fir-wood,	1.11
Birch,	0.80
Oak,	0.75

Many varieties afford as much as five and even ten per cent. more, especially if the wood has been grown upon silicious soils.

A remarkable property of charcoal is, that it absorbs with avidity gases and vapors, condensing them within its pores to a most surprising extent, as shown in Vol. I., p. 764. In consequence of this property, it cannot be exposed to moist air for any length of time, without exerting a hygroscopic action, and assimilating a variable per centage of water, in proportion to the time of exposure and the humidity of the atmosphere. From experiments made with freshly prepared charcoal, NAU obtained the subjoined numbers after exposing the samples twenty-four hours to an atmosphere loaded with moisture:—

	Amount of water absorbed in twenty-four hours Centesimally represented.
White beech charcoal,	0.80
Ash,	4.06
Oak,	4.28
Birch,	4.40
Larch,	4.50
Maple,	4.80
Pine,	5.14
Red beech charcoal,	5.30
Horse-chestnut,	6.06
Elm,	6.60
Alder,	7.93
Scotch fir,	8.20
Willow,	8.20
Italian poplar,	8.50
Fir,	8.90
Black poplar,	16.30

This proportion slowly increases when the exposure is prolonged, as proved by WERLISCH, who found that one hundred parts of charcoal, weighed on the 24th of June, became—

On the 30th of June,	104.35
" 7th of July,	105.63
" 16th "	106.57
" 29th "	107.62
" 20th of August,	108.16
" 17th of September,	108.44

These numbers do not indicate, however, the actual

amount of contained moisture, as the charcoal had not been taken immediately from the melier, so that it might have already absorbed from three to four parts of water, as the former table shows.

The lower the temperature at which the carbonization has been effected, the proportion of water is greater. The results of VIOLETTE's experiments on this subject are given below. The samples, consisting of charcoal from black alder, prepared at increasing temperatures, were exposed in a room, the air of which was saturated with moisture, and the amount of absorption determined every eight days, no numbers being taken till the results of two successive trials agreed:—

Temperature of carbonization Deg. Fahr	Quantity of water absorbed by 100 of charcoal	Temperature or carbonization Deg. Fahr	Quantity of water absorbed by 100 of charcoal
302	20.862	554	6.920
320	18.220	572	7.608
338	18.180	590	7.200
356	16.660	608	5.554
374	11.626	626	4.504
392	10.018	644	5.904
410	9.742	662	5.894
428	8.954	680	4.704
446	8.800	1873	4.676
464	6.666	2012	4.444
482	7.406	2232	4.760
500	6.836	2372	2.224
518	6.306	2732	2.204
536	7.870		

To account for the very high numbers with which the table commences, it is to be observed that the product resulting from the low degrees of temperature was not more than half-burned charcoal, hence its proportionally greater hygroscopic power.

The density of charcoal depends chiefly on that of the wood; hence it is evident that the relative weight of the wood will afford a good idea of the nature of the charcoal produced from it. This fact is of much importance, as the value of the material for fuel may, to a considerable extent, be deduced from its specific gravity. The value of this, for several species of wood, as determined by HASSENFRATZ, is as follows:—

	Specific gravity.
Birch wood charcoal,	0.203
Ash,	0.200
Wild service wood,	0.196
Red beech,	0.187
White beech,	0.183
Elm,	0.180
Red fir,	0.176
Maple,	0.164
Oak,	0.155
Pear,	0.152
Alder,	0.134
Lime,	0.106

These numbers, however, merely indicate the weight of various samples when the interstices have been filled with air, and, therefore, do not represent the true gravity. In the appended table, the real specific gravity as determined by VIOLETTE is given. The course which the latter adopted was to immerse the sample, already weighed in air, in a flask three-quarters full of distilled water, allowing it to remain exposed to light for eight or ten days; by filling the flask at the end of this period to the usual mark, and then determining the total weight, and from this deducting that of the flask and liquid, the difference by the usual formula gave the specific gravity:—

**DENSITY OF THE CHARCOAL OF BLACK ALDER PREPARED
AT INCREASING TEMPERATURES.**

Heat of carbonization. Deg. Fahr.	Density of charcoal.	Heat of carbonization Deg. Fahr.	Density of charcoal.
302	1.507	626	1.428
338	1.490	662	1.500
374	1.470	810	1.709
410	1.457	1873	1.841
446	1.416	2282	1.862
482	1.413	2732	1.869
518	1.402	fusing point of	2.002
554	1.406	the retort, }	
590	1.422		

The density in this case is therefore greater than that of water, but still it varies to a certain extent with the temperature at which the substance has been prepared; thus the charcoal obtained between the temperatures 302° and 518° Fahr. decreases in density from 1.507 to 1.402; while, on the contrary, that which is afforded between 518° and 662° increases from 1.402 to 1.500; and from this point the density continues to increase, till, at the fusing point of the vessel, it becomes double that of water.

Before proceeding to the other materials which constitute fuel, a few observations may be made on the power of charcoal to conduct heat, and the facility with which it undergoes combustion.

It is a well-known fact that the product resulting from a high temperature, or in other words, black charcoal, is a much better conductor of caloric than that formed under the influence of a lower heat; it requires also a higher temperature to ignite it; but when this is effected, and an adequate supply of oxygen is kept up, the combustion proceeds steadily, and the heat given off is regular and sustained. Considerable difficulty is found in making accurate determinations of the conducting power of charcoal. The ingenious method of M. VIOLETTE deserves particular notice, as it affords in a simple manner the conducting power of this substance, and may, by a slight adaptation, be rendered available for determining questions of importance concerning the philosophy of heat in bodies.



Fig. 37 shows the arrangement of the apparatus, in which A represents a glass flask half filled with water and heated by a lamp; this is connected with another glass cylinder, B, closed by tightly fitting bungs, by means of a glass tube, C. In the superior cork or cap of the tube, B, is an opening which receives a third tube, D, nearly filled with mercury, in which is immersed the sample of charcoal, the conducting power of which is

to be determined. This is seen in the figure at E, and in its upper end there is made a perforation for the reception of a small mercurial thermometer, F, for the purpose of registering the rays of caloric conducted by it. The entire length of the sample, in the experiments made by the inventor of the apparatus, was 0.984 of an inch, of which 0.236 of an inch was immersed in the mercury; 0.195 of an inch of the sample intervened between the latter and the bulb of the thermometer. The source of the heat was the steam circulating in the vessel, B, and escaping through the outlet, C. A portion of the caloric of the vapor was abstracted by the mercury, so that it was retained at about 204.8° Fahr. The numbers given in the annexed table were obtained by noting the register of the thermometer at intervals of five minutes till the indication remained stationary: this happened after fifteen minutes' immersion. By employing a bar of iron of the same dimensions as that of the charcoal, and introducing the bulb of the thermometer in a like manner, a comparison was instituted between the charcoal and this substance of known power of conduction.

**CONDUCTING POWER OF CHARCOAL OF THE SAME WOOD—
BLACK ALDER—PREPARED AT INCREASING TEMPERATURES:—**

Temperature Of the carbonization.	Indication of the Thermometer.				Conducting power of Charcoal compared with that of Iron repre- sented by 100
		After 5 minutes.	After 10 minutes	After 15 minutes	
316° Fahr.	27.00	56.00	57.0	57.5	59.5
392 "	27.00	57.00	57.5	58.0	60.1
482 "	27.00	57.50	57.5	58.0	60.1
572 "	27.00	58.00	59.0	59.5	61.6
1873 "	26.50	61.00	62.0	62.0	64.2
2282 "	26.50	62.00	62.50	63.0	65.2
2732 "	26.00	63.00	63.5	64.0	66.8
Charcoal of gas retorts.	26.00	81.00	82.0	82.0	84.7
	22.00	96.50	96.5	96.5	100.0

The numbers in the last column were obtained by multiplying those of the preceding one by 1.036. Between the temperatures 572° and 752° the conducting power is low, and is nearly the same in the wood and the charcoal produced from it; but when the heat is elevated, the density of the charcoal increases rapidly, till it is about two-thirds that of iron.

Regarding the combustion of charcoal, it will be observed, upon taking pieces of it, produced by different modes of working or by unequal degrees of heat—plunging one end of each in the flame of alcohol till ignited, and then allowing it to rest in tranquil air—that very different phenomena will be exhibited in the combustion. The charcoal made at low temperatures, say between 302° and 482° Fahr., burns with a long yellow flame, disengaging large volumes of smoke, and retaining the temperature of combustion for about fifteen minutes, at the end of which time the cylinder will have burned about half an inch. On the other hand, if the wood has been submitted during carbonization to a heat between 482° and 809°, the combustion of the charcoal under the same circumstances is characterized by a clearer flame, which is less fuliginous and persistent, and by being continued for a longer time, more especially with those samples prepared between 482° and 662°. The charcoal pro-

pared at 809° does not burn so well as any of the samples obtained at a lower heat, nor does the ignition continue so long. When the carbonization is effected at the higher degrees represented in the foregoing table, the cylinder of charcoal, on being introduced into the flame, becomes red-hot like a bar of metal, affording no flame, and is extinguished immediately on withdrawing it, without giving any indication of combustion or leaving a coating of ash. In this last case, the fingers are unable to hold the cylinder whilst its end is in the flame for any length of time, in consequence of the freedom with which it conducts the heat.

All the preceding samples, when reduced to powder, present the same phenomena with respect to combustion as when in solid pieces, only with greater intensity, because, on account of the air interposed, the ignition is easily propagated and maintained. When, however, the experiment is conducted in a very tranquil atmosphere, the burning ceases after a part is consumed. This effect must doubtless be owing to the carbonic acid, which, being heavier than common air, does not ascend with sufficient freedom to permit the oxygen of the latter to come in contact with the burning matter.

In many manufactories where this article is required in powder, great care must be exercised, as it often happens that spontaneous combustion takes place. The most inflammable charcoals take fire at 572°, and those that are prepared at the latter heat invariably ignite at a temperature varying from 680° to 716°, according to the nature of the wood. Charcoal, from light and porous woods, always burns more freely than that obtained from the hard and dense kinds; but even the same wood furnishes charcoal that ignites with greater or less facility according to the temperature at which it has been prepared, as may be seen from the following table:—

TABLE SHOWING THE TEMPERATURE AT WHICH THE CHARCOAL, FROM THE SAME WOOD, PREPARED AT INCREASING TEMPERATURES, BURNS.

Charring temperature	Temperature at which the charcoal takes fire.	Charring temperature.	Temperature at which the charcoal takes fire.	
500°	614	1873	1122 to 1472	
518	644 to 680	2282		
536		2472		
554		2732		
572	680 to 698	Charcoal prepared at the point of the fusion of the cylinder, } 2282		
590				
608				
626				
644	752			
662				
8093				

Other particulars concerning charcoal, so far as relates to the manufacture of gunpowder, will be introduced under that head.

PEAT.—Another article of fuel, much employed for domestic purposes, as well as for many manufactures, in which it has lately found admittance, is *Peat*. Such is the name by which the brownish-black spongy substance, found in almost every country, filling up cavities, and constituting what is termed *bog*, is known. It is a product of vegetal origin, but differing from wood as well in the nature of the growth, as from the change which it has undergone atomically through the combined agency of time and pressure. It was once supposed that this formation was, in point of time, coeval

with the disposition of the face of the country into hills and valleys; by some it was considered a bituminous deposit from the sea—the wreck of floating islands previous to the great convulsions which the earth underwent during the formation of the present continents and islands. By others it was even regarded as an organic substance in a state of vitality, and actually growing; but all these notions are now abandoned, and a more rational and philosophical view of its nature and production has been arrived at. From examining its structure, it has been found that it is constituted of vegetal matters, generally mosses and species of aquatic plants in different stages of decomposition; and from this circumstance, as well as from the general appearance of the localities where peat abounds, its formation is now accounted for in the following manner:—

At the present day it may be observed, that where pools collect, the soil under which is retentive, the water not being absorbed, stagnates, and, provided the surface evaporation is not great, forms a pond. Round the borders of this, various kinds of aquatic plants, sedges, rushes, *et cetera*, soon make their appearance, and by reproduction, gradually creep in towards the centre till the whole surface becomes covered. In course of time, when several races of these have succeeded one another, and mud and slime have accumulated at the roots and round the decaying stems, a spongy mass results, which is well calculated for the propagation of moss. Under a constant supply of moisture, these various species continue to luxuriate, and, by progressive growth and cremacausis, ultimately give rise to a composition in every respect similar to that constituting the various peat-bogs. That some such natural process has been the cause of the production of peat appears from its composition and the localities in which it is found. These are chiefly in the temperate zones, where evaporation is slow, and the atmosphere is generally more or less saturated with humidity. It may be conceived that in the origin of these formations, the retention of the water, whether from rain or springs, in extensive basins, led at first to the development of vegetal growth in the manner above indicated, and that the necessary moisture being supplied in abundance, the accumulation became so rapid, that ultimately the surface assumed the appearance of land; and, as decomposition proceeded, a degree of solidity was given to the mass to support denser bodies, such as shrubby plants. It would appear that this organic growth was rarely restricted to the original basin; but that, as it accumulated, it spread over adjacent land, which, in time, became a morass. Evidence conclusive enough of this exists in the fact, that whole forests, of almost every description, such as oaks, firs, ash, birch, yew, willow, *et cetera*, have been overwhelmed under its gradual but steady advancement, and are found in all positions at the bottom of peat-bogs. Generally, this formation is met with in climates of a moist nature, in level countries, where imperfect natural drainage exists, although it is found in considerable beds in upland districts. The very extensive peat moors on the coasts of the German Ocean, especially in Holland and Northern Germany, and in many tracts in Ireland and Scotland, are examples of the

former; whilst the deposits encountered high up the Alps, in the Vosges, and in the Jura, illustrate the latter. In mountainous districts, in addition to the imperviousness of the rock to the moisture, the constant formation of clouds upon those elevated regions favors the growth of the mosses and plants, the decomposition of which contributes to the production of quagmires.

DARWIN states that, in the Southern hemisphere, peat does not occur nearer to the equator than the latitude of 45° ; that the composition there met with results from the decomposition of the plants and grasses. The circumstance that no mosses, so far as can be ascertained by strict examination, enter into the species of peat found in South America, favors this view.

The extent and depth of the peat-bogs vary considerably in the different countries where they are found, and depend on circumstances quite distinct from each other. It is evident that the area which they may occupy is intimately connected with the distribution of the water, from whatever causes. In Holland and North Germany, the water of the ocean seems to have largely contributed to the moisture in which they originated. The peat-moors of the Grand-duchy of Hesse would appear to be occasioned by the overflow of the Rhine, whereby these tracts were irrigated, and the waters remaining, and necessarily becoming stagnant, the place was soon changed, and, instead of remaining a swampy district, it ultimately became a morass. On the other hand, the thickness of the beds of peat, seems, from repeated observation, to be dependent upon the nature of the subsoil. Where the bottom is quartzose, the deposit is invariably not very thick; but if it be such as yields by disintegration a clayey coating, the depth and extent are much more considerable. The morasses of Holland are to a considerable extent about six feet in depth, as are likewise those in upland situations; whilst many of the peat bogs in Ireland are from thirty to forty feet in depth. On intersecting these, it appears from the fact of layers of gravel, clay, shells, *et cetera*, being interposed horizontally, that these tracts have been swept over with violent currents of water; such layers, however, are never more than a few feet in thickness, and, seem to have retained all the conditions favorable for the growth of the plants conducive to the formation of peat.

From its physical constitution, this substance may be regarded as a kind of fossil fuel, and, undoubtedly, it is one of the most extensive sources known. Viewing it as the product of the decomposition of plants carried on through a long succession of ages up to the present, it is natural to expect that when cut vertically, differences should appear showing the advancing state of decomposition. In every instance, almost, this progressive change is exhibited, and, consequently, peat is classed into—

Recent Peat and Older Peat, from the appearance it presents. The former bears distinctive traces of its origin in the roots, leaves, and stems of plants, the structure of which is still retained. It is very porous, tough, and elastic in some tracts; but in others, especially where the bog is well drained, very brittle. The color varies, with the age and the progress of the de-

composition, from a light to a blackish-brown. In the second, to which the preceding gradually inclines, no traces of fibrous matters—such as roots, stems, or leaves—are observed, but it presents when cut a pitchy shining hue—is dense and fine in the grain. Preference has always been accorded to this as a fuel from its superior gravity, and the greater heat which it produces when undergoing combustion. From the change which the vegetals pass through, it is evident that the usual process of putrefaction is carried on in the ordinary way at the commencement; but as the surface grows, and contact with the air is cut off, the mass is left to the play of the affinity of its elements, rendered more active by the pressure which it has to sustain. The alteration is attended with the evolution of marsh gas—bihydride of carbon $C H_2$ —and carbonic acid, in the same way as in every case of partial destructive distillation; but from the excess of moisture present, it is evident that this action cannot, in the case of peat, be so complete as in coal, which is analogous in nature. Many bodies are detected in peat, however, which are not contained in coal, although the ultimate elements of both are the same. SPRENGEL detected in peat considerable quantities of ulmic acid—known also by the names *ulmin*, *humus*, *gein*, and *geic acid*—the composition of which, as obtained from turf, is expressed by the formula $C_{40} H_{15} O_{12} N$; and when procured from mould, by $C_{40} H_{15} O_{14} N$. This principle is dissolved out by alkalis, and precipitated from their solutions by acids in brownish flakes; this, however, as also the other varieties of resins examined by MULDER, are of little use hitherto in the arts.

The density of peat varies with the relative position in which it is found, with the thickness of the stratum, and the amount of mineral matters which it contains. Freshly cut, it is saturated with water to the extent of eighty to ninety per cent. in some cases, and, when subjected to the ordinary process of air-drying, it retains a large quantity of this, amounting sometimes to thirty per cent.

The estimation of the gravity in this state would lead only to relative approximations, even if the percentage of moisture was known, and the species examined had undergone about the same degree of decomposition. As already intimated, however, the latter principally determines the difference of specific weight in peat from the same cutting. KARMARSII arrived at the following results with regard to Hanoverian peat:—

Species	Specific gravity.
1. Light-colored young grass peat, nearly unchanged moss,	0.113 to 0.263
2. Young brownish-black peat—an earthy matrix intersected with roots,	0.240 to 0.600
3. Old earthy peat without any fibrous texture,	0.564 to 0.902
4. Old or pitch peat,	0.639 to 1.039

Of twenty-seven samples of peat examined by Sir ROBERT KANE and Dr. W. K. SULLIVAN, the results, as stated in their report in 1851, show that the maximum density was 1.058, and the minimum 0.235, a great many being under 0.600, as may be seen from the following tabulation of their gravities, coupled with the constituents of the ash, to which reference will be made further on:—

FUEL—COMPOSITION OF PEAT-ASH.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Specific gravity,	0.297	0.405	0.669	0.450	0.351	0.661	0.335	0.476	0.655
Potassa,	0.362	1.323	0.461	0.401	0.221	0.198	0.491	0.211	0.247
Soda,	1.427	1.902	1.399	1.330	0.712	0.590	1.670	0.651	0.496
Lime,	26.113	36.496	40.920	37.873	33.240	25.860	33.037	29.716	24.944
Magnesia,	3.392	7.634	1.611	5.127	1.904	1.207	7.523	1.204	1.285
Alumina,	4.180	5.411	3.793	0.271	0.240	0.371	1.680	0.298	0.360
Sesquioxide of iron,	11.591	15.608	15.969	14.802	12.760	18.746	13.281	20.372	19.405
Phosphoric acid,	1.461	2.571	1.406	1.257	1.222	0.874	1.438	1.066	0.242
Sulphuric acid,	12.403	14.092	14.507	11.814	21.470	23.630	20.076	22.664	10.742
Hydrochloric acid,	1.568	1.482	0.983	1.367	0.840	0.622	1.747	0.439	0.335
Silica in compounds decomposable by acids,	0.980	3.595	1.111	1.002	1.672	0.896	2.148	0.645	1.082
Sand and silicates undecomposable by acids,	22.519	2.168	2.107	4.722	13.147	14.430	7.683	11.180	26.789
Carbonic acid,	13.695	7.761	15.040	19.722	12.060	12.240	8.340	10.782	13.890
Total,	99.691	100.043	99.307	99.688	99.488	99.654	99.120	99.228	98.817

	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.
Specific gravity,	0.434	0.984	0.681	0.523	0.274	0.394	0.437	0.323	0.924
Potassa,	0.641	0.347	0.181	0.291	0.966	0.407	0.665	0.668	0.280
Soda,	1.875	0.679	0.550	0.586	1.038	2.074	2.605	1.709	2.180
Lime,	22.702	45.581	29.323	38.692	35.113	33.397	33.554	31.553	30.714
Magnesia,	6.809	1.256	3.425	2.372	4.687	11.293	9.229	9.439	9.237
Alumina,	1.109	0.129	0.672	0.408	1.627	0.677	1.707	2.027	2.027
Sesquioxide of iron,	29.854	15.974	19.095	15.537	14.322	18.500	18.366	6.012	19.797
Phosphoric acid,	2.019	0.188	0.975	0.878	0.828	0.744	1.300	1.286	1.290
Sulphuric acid,	16.381	44.371	16.238	14.822	25.409	13.550	23.505	25.602	20.857
Hydrochloric acid,	1.591	0.337	0.636	0.657	1.090	2.804	3.263	0.698	3.128
Silica in compounds decomposable by acids,	0.737	1.043	3.255	5.808	5.607	5.998	4.449	5.159	3.096
Sand and silicates undecomposable by acids,	14.505	2.653	8.884	14.181	4.340	6.593	3.040	6.282	3.163
Carbonic acid,	1.470	16.120	15.984	5.842	5.003	3.006	....	9.864	3.570
Total,	99.693	99.678	99.218	100.074	100.030	99.993	99.653	99.979	99.369

	XIX.	XX.	XXI.	XXII.	XXIII.	XXIV.	XXV.	XXVI.	XXVII.
Specific gravity,	1.058	0.481	0.620	0.280	0.546	0.855	0.402	0.441	0.858
Potassa,	0.744	1.667	0.271	0.146	0.247	0.219	0.370	0.028	0.158
Soda,	0.704	2.823	1.491	0.466	1.150	0.855	2.628	2.832	0.527
Lime,	40.623	20.907	13.667	8.192	22.332	40.079	27.732	26.551	12.432
Magnesia,	4.352	15.252	16.994	4.702	5.608	4.035	6.875	12.580	3.095
Alumina,	1.671	2.034	0.259	10.705	0.932	0.895	1.521	3.298	5.991
Sesquioxide of iron,	10.368	17.040	26.614	15.052	29.979	14.160	7.451	12.116	30.725
Phosphoric acid,	1.114	1.147	1.339	1.557	0.699	0.632	1.670	2.022	0.526
Sulphuric acid,	21.208	23.375	22.691	13.974	31.612	22.295	20.389	22.401	14.518
Hydrochloric acid,	1.052	1.424	1.180	0.196	0.993	0.781	2.932	2.581	0.151
Silica in compounds decomposable by acids,	6.317	6.634	2.719	12.476	2.751	1.295	7.709	5.474	9.101
Sand and silicates undecomposable by acids,	3.710	10.682	11.673	31.198	3.775	5.496	10.088	17.711	22.721
Carbonic acid,	4.981	6.721	....	....	....	9.101	10.460	1.220	....
Total,	99.844	100.006	98.964	98.928	100.069	99.843	99.825	98.751	99.945

The carbonic acid found in the above analyses is, in nearly every instance, much less than what is required to saturate the lime, supposing the whole of the sulphuric acid to exist as sulphate of lime; this is accounted for by the high temperature necessary to incinerate the peat, having driven off the greater part of the carbonic acid.

- I.—Light, spongy, surface-peat, of a reddish-brown color, and composed almost entirely of *Sphagnum*, species of which are still distinguishable; from near Monastrevin.
- II.—Light surface-peat, of a reddish-brown color, containing small roots of *Erica*, also leaves of grasses and *Carex*; from Mount Lucus Bog, near Phillipstown, King's County.
- III.—Rather dense peat, of a dark reddish-brown color, in which the structure of moss is still observable; from the same locality as No. II.
- IV.—Light reddish-brown fibrous moss-peat, in which the *Sphagnum* is almost unaltered, as well as leaves of *Carex* and other plants, and the roots of species of *Erica*; from Twickuevin, Kildare.
- V.—Upper layer of fibrous red bog, composed entirely of *Sphagnum*, *Hypnum*, and other mosses; from Derrymullen Station of the Irish Amelioration Society.
- VI.—Dense peat, of a black-brown color, in which vegetal structure is nearly obliterated, but in which the leaves of grasses and *Carex*, with twigs of hazel and birch, are sometimes found; from Wood of Allen, Great Timahoe Bog.

- VII.—Light surface-peat, of a pale yellowish-brown; from Wood of Allen. The mass is very open-grained and fibrous in this sample, and *Sphagnum* and *Hyssopus* are readily distinguishable.
- VIII.—Middle layer of the same bog, of a deep-reddish color. The mass is tolerably compact, but fibrous, having the structure of the mass very indistinct. A very few roots of *Erica*, and small twigs of birch and alder, and fir scales are found in it.
- IX.—Lower layer of the same bog, and from the same locality. This variety is compact and dense, of a deep blackish-brown color, with an earthy almost conchoidal fracture, and exhibiting a resinous lustre when rubbed. Vegetal structure nearly obliterated.
- X.—Good compact peat, of a blackish-brown color, and consisting principally of moss, with a number of *Erica* and grass roots and *Carex*. This sample is from Riversdale Bog, near Kimegad, and is used as fuel in Dublin.
- XI.—An extremely hard and compact peat, having the vegetal structure entirely obliterated, and exhibiting when broken a resinous conchoidal fracture. Scales of fir-trees and twigs of birch and alder, *et cetera*, occur in it; it is a valuable fuel. Locality—Riversdale Bog, near Kimegad.
- XII.—Very dense, dark, reddish-brown peat, from Anadruce and Cloncreim, on the Royal Canal. In this peat the vegetal structure is only occasionally perceptible.
- XIII.—Rather dense peat, of a dark reddish-brown color and compact structure, from bogs of Rathconnell, Wood Down, and Great Down, near Mullingar. *Sphagnum* indistinct, but leaves of the flag and stems and roots of *Erica* occur in a very perfect state in it.
- XIV.—Upper layer of a fibrous bog in the neighborhood of Banagher. It is a spongy mass, of a yellowish-red color, composed of almost unaltered *Sphagnum*, with occasional roots of *Carex*, *Erica*, *et cetera*.
- XV.—Rather compact peat, of a reddish-brown color, from the same locality as the preceding sample. In this kind, vegetal structure is very perceptible, although undistinguishable; the roots of the *Erica* are abundant, but the greater part is evidently derived from moss.
- XVI.—A more compact peat than No. XV., from the same bogs, consisting of fibrous or red bog, of a light reddish-brown color. Like the foregoing, the species is indiscernible in this, although organic structure is visible. Roots and leaves of *Carex* are exceedingly abundant in it.
- XVII.—Light surface-peat, of a pale reddish-brown color, from the bogs of Clonfert and Kilmore, at the mouth of the Suck, near Banagher. The mass is spongy, and is composed of almost unaltered *Sphagnum*, with a few stems and roots of *Erica*.
- XVIII.—Peat from the same locality. It is rather compact but fibrous, and of a light reddish-brown color passing into black.
- XIX.—An exceedingly dense peat, of a conchoidal earthy fracture, from Athlone bog. In this the vegetal structure is almost completely destroyed; but when apparent, indicates remains of *Carex*, grasses, and *Erica* in abundance.
- XX.—A rather dense peat, of a blackish-brown color, in which the structure of moss is no longer visible, but abounding in remains of *Carex*, grasses, and roots and stems of *Erica*; from the Curragh or Clonbourne bogs near Shannon Bridge.
- XXI.—A dense peat, of a dark reddish brown color, from bogs along the Shannon. Remains of *Carex* and grasses are abundant in this variety, but *Sphagnum* is very indistinct. It is used in steamers plying on the river.
- XXII.—A light fibrous peat, of a reddish-brown color, formed evidently of a great number of plants, and in which the structure of moss is very distinct. Species of *Sphagnum* and *Hyssopus* are observed, and also remains of *Carex* and grasses, the roots of *Erica*, the bark of birch, and probably alder-twigs in abundance. It is from the same locality as No. XXI.
- XXIII.—A very dense peat, of a blackish-brown color, of a compact though very indistinct structure. The remains of *Carex* are abundant, as also roots of *Erica*. It forms an excellent fuel. Locality the same as No. XXI.
- XXIV.—A very dense blackish-brown compact peat, from the same locality as No. XXI. In this species, vegetal structure is almost obliterated. It has an earthy fracture, and is full of the tubes of the bark of hazel, birch, and alder; occasionally scales of pine bark and leaves of *Carex* and grass are met in it.
- XXV.—A rather dense reddish-brown peat. The structure of this is indistinct, but altered *Carex* leaves and fragments of twigs and roots are observed in it. Locality the same as No. XXII.
- XXVI.—Rather compact and moderately dense peat, of a dark reddish-brown color. Structure of moss almost obliterated. Fracture earthy. Abundance of leaves, stalks, and roots of grasses, *Carex*, *et cetera*. Same locality as No. XXII.
- XXVII.—A dense jet-black peat. Structure of moss completely destroyed. Fracture earthy, tending to conchoidal; assuming resinous lustre when rubbed. Abundance of remains of *Carex* leaves, and a very few fragments of bark, apparently of hazel. Same locality as No. XXII.

From the results of the ultimate analysis of dried peat, it is observed that the numbers which are found do not correspond with the analysis of dried wood. The following analyses by REGNAULT and MULDER show the centesimal contents of carbon, hydrogen, and oxygen:—

Locality.	Carbon.	Hydrogen.	Oxygen.
Vulcaire,.....	59.57	5.96	34.47 Regnault.
	60.40	5.86	33.64 Mulder.
Long,.....	60.08	6.21	33.73 Regnault.
	60.89	6.21	32.90 Mulder.
Champ de Feu,...	60.21	6.45	33.34 Regnault.
	61.05	6.45	32.50 Mulder.
Friesland,.....	59.42	5.87	34.71 "
Friesland,.....	60.41	5.87	34.02 "
Holland,.....	59.27	5.41	35.35 "

In these samples, the numbers are calculated after deducting the ash. It is a well-ascertained fact that a greater or less quantity of nitrogen is invariably contained in peat, but this element appears to have been overlooked in the preceding. To show the average extent of the contents of nitrogen, the following analyses, selected from the *Dublin Journal of Industrial Progress*, so ably edited by Professor SULLIVAN, are submitted. The materials were taken from the same localities as mentioned in the foregoing table; but before subjecting them to analysis, they were thoroughly exsiccated at a temperature of 220° Fahrenheit:—

	Carbon	Hydrogen.	Oxygen.	Nitrogen, mean.
Surface-peat, Phillipstown,.....	58.694	6.971	32.883	1.4514
Dense peat, Do.,.....	60.476	6.097	32.546	0.8806
Light surface-peat, Wood of Allen,....	59.920	6.614	32.207	1.2588
Dense peat, Do.,.....	61.022	5.771	32.400	0.8070
Surface-peat, Twicknevin,.....	60.102	6.723	31.288	1.8866
Light surface-peat, Shannon,.....	60.018	5.875	33.152	0.9545
Dense peat, Do.,.....	61.247	5.616	31.446	1.6904

Kane and Sullivan.

Annexed are further analyses referring to the same subject by KANE and RONALDS:—

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	
Kilbeggan, Westmeath,.....	61.040	6.670	30.47		Kane.
Kilbaha, Clare,.....	56.630	6.330	34.48		
Cappoge, Kildare,.....	51.05	6.850	39.55		
Ochta, in Eastern Russia,.....	39.084	3.788	51.088		Woskressensky.
Peat 4.5 feet from surface, Tuam, Ire- land,.....	57.207	5.655	28.949	3.067	Ronalds.
" 3.5 feet " "	58.306	5.821	29.669	2.509	
" 4.5 feet " "	59.552	5.502	28.414	1.715	

Comparing these numbers with those afforded by dry wood, it would appear—viewing the peat as a compound of equal weights of water and carbon, and supposing that the oxygen in the wood is proportioned to the hydrogen to form water—that an excess of ten per cent. of carbon and two per cent. of hydrogen is contained in the peat over the quantity of these elements which wood affords, but the amount of water is reduced ten per cent. This difference in the centesimal amount of the elements might have arisen from the decomposition which the matter of the peat has undergone.

Peat always contains earthy matters in greater or

less proportion according to the thickness of the stratum and its position. Surface-peat generally contains less mineral matters than the second strata, which often possesses so much of these as to render it useless in point of economy as fuel. In this, as well as from the nature of those matters, it essentially differs from wood. These substances are left when the peat is consumed in contact with air in the form of ash, and, from the nature of the ingredients, it presents various appearances from white to grey and ochrey. The per centage of the ash left when peat is burned is given in the annexed table, which embraces almost every variety of this substance:—

Variety of Peat.	Ash.	Observer.
Grass peat—brownish-yellow,.....	1.0 — 1.5	Karmarsh.
Pitch peat,.....	1.2 — 8.0	
Young peat—dark brown,.....	5.0 — 7.0	
Old earthy peat,.....	10.0	Suersen.
Black firm peat, from Neumünster,.....	2.2	
" " Smeldingen,.....	7.2	Schübler.
Brown loose peat, from Schweiningen,.....	2.3	
Very old peat, from Vulcaire, near Abbeville, ..	5.58	Regnault.
" " Long, ".....	4.61	
Peat not so old, from Champ de Feu, near Abbeville,.....	5.35	Achard.
" from near Berlin, 1st stage,.....	9.30	
" " 2d ".....	10.20	
" " 3d ".....	11.20	
Black old peat, from Müglitz,.....	14.40	Einhof.
Young brown peat,.....	14.30	
Moor in Eichfeld, 1st sort,.....	21.50	Buchholz.
" " 2d ".....	23.00	
" " 3d ".....	30.50	
" " 4th ".....	33.00	
Ash in forty-one sorts, from the Erzgebirge,.....	1.00 — 24.0	Winkler.
" three varieties, from Holland and Friesland,.....	4.61 — 5.580	Mulder.
" twenty-seven varieties, from the central Bog of Allen in Ireland,.....	mean 1.120 — 7.898	Kane and Sullivan.
	mean 2.62	
" three varieties, from the neighborhood of Tuam in the west of Ireland,.....	3.695 — 4.819	Ronalds.
	mean 4.545	
" nine varieties, from Schnaditzer bog, near Schwemsal, in Saxony,.....	5.300 — 37.10	Wellner.
	mean 18.47	

Thus it will be seen, that in some of these varieties no less than one-third of the entire weight consists of incombustible substances, which, it is needless to say, is too large a quantity, and prevents their being much employed as a source of heat. Such varieties are, however, valuable as manures, owing to their containing a large amount of phosphates and other salts, that serve to enrich the soil.

Very copious details of the composition of the ashes of most of the peats of Ireland have been given in a former table, at page 52, to which the reader is referred.

Peat, when distilled in close vessels, gives off various products similar to those which wood affords, besides ammonia, and some bodies of a fatty nature, which are much in demand in many departments of the industrial arts. In its natural state it is highly

antiseptic, to which may be attributed the long period which is required before the traces of the substances originating it are effaced. This quality has been further proved by the wood which is found without being in the least injured, although buried thirty feet deep in it for centuries. Not only these, but human bodies and remains of animals—the latter now extinct—and other substances prone to putrefaction, have been found at a great depth in a high state of preservation.

Where peat bogs abound, as in those countries already alluded to, the inhabitants make use of the article, after undergoing a very simple preparation, as fuel for domestic uses. With the exception of a few localities on the Continent, but little has been done to bring peat into requisition in those arts which are

intimately associated with heat, although the value of the charcoal which the substance affords as a calorific agent has been attested by practical skill and theoretical calculations. Attempts have long been made in Holland and some states of Germany, to render peat more profitable, as well in manufacturing operations as for domestic purposes; but it is remarkable that in a country such as Ireland, where, compared with other nations, the cost of labor is low, with one exception nothing has been done to convert her area of *two millions eight hundred and thirty thousand acres* of the finest bogs in the world to her advantage, although, if properly treated, they might prove a source of immense wealth. This neglect of the national interests seems still more inexplicable, when it is considered that the wealth requisite for successful manufacturing enterprise is already in the hands of the people, but lies a mere waste, useless to the possessor and to the universal interests of the community. It would appear, however, that something like an incipient spirit of enterprise is growing in the Irish mind, and, if this be fostered by the hand of science, doubtless, ere long, many of the hidden treasures which lie at the feet of the impoverished population, will be developed to the advantage of the parties immediately concerned, and the prosperity of the nation at large.

For domestic purposes, the peat is prepared by a very simple course of operations, differing sometimes according to its nature and thickness.

In every case the surface layer, which contains the living plants and their roots in the natural state, is stripped off to the depth of six to nine or twelve inches. The material is then cut with a kind of spade known as the *slane*, which has a wing bent at right angles to the blade of the instrument, so as to form with the latter two sides of a square. Sometimes two such wings or ears are added to the tool, and at the outer end these are united by a plate of iron which gives to it the appearance of a hollow rectangular cube, open at both ends. By this instrument the peat is cut in long square masses, and then spread upon the sward, where it spontaneously loses its water. After the bricks have acquired sufficient consistency, they are piled up on end so as to afford a more thorough exposure to the air; and finally, when desiccation has advanced, the turf, as it is then called, is piled together, being built round by a kind of clamp construction of the sods or bricks, and left till the material becomes as dry as it can be made by exposure to the air. Such is the mode adopted when the peat is sufficiently elastic to bear being so handled without breaking; when, however, the material is brittle and will not admit of being used in this way, it is dug out with ordinary spades, shovels, *et cetera*, and all roots, stones, and such like solid bodies picked out. It is then spread in a layer of from twelve to eighteen inches in thickness, watered, and brought to a homogeneous mixture, either by the tramping of men or beasts, where the latter can be employed. Afterwards the surface is smoothed and moulded in forms, either with the hand or a small mould which indents the surface. When the excess of water has drained off and the peat becomes consistent, the bricks are cut

out with a long knife, and dried in the manner already indicated. In many moors or fens the peat is so surcharged with water that it cannot be extracted even with the spade; in this case the workmen employ a kind of dredge, by which the material is collected. It is deposited on a sloping sward, and after the superabundance of water has drained off and the mass becomes more consistent, it is moulded into bricks. The latter processes are usually resorted to in France, Germany, and most other localities where peat abounds. In Holland a different course is pursued, which, though more circuitous, is notwithstanding more effectual in producing a denser fuel than can be obtained by the foregoing methods. The upper stratum, which is light and fibrous in its nature, is nearly always moulded with the *slane*, though sometimes it is subjected to the same operations as the under layer. Generally, this is scooped out with a kind of ladle when it is not too wet, and carried to the tempering ground; where, by sprinkling with water, tramping with the feet, and tempering with a rake, it is brought to a homogeneous consistence, and freed from stones, bits of wood, leaves, and the like. In case the matter is slimy, and so thin that it will not admit of adhering together in masses, another kind of tool is employed, enabling much more peat to be abstracted, with less water, than if the ordinary iron ladle dredge were used. It consists of a ring of iron, the edge of which is sharp, attached to a long handle; the side of this band is perforated for the purpose of affixing the body, which is a thick cloth, and the whole forms an instrument not unlike a fisherman's landing-net. Much more peat is taken up by this, and the excess of water filtering through the meshes of the tool, the peat is in a state which will admit of being immediately worked. This very slimy material is kneaded in a kind of trough or tub, till it becomes thoroughly blended together. In this state it appears like a kind of mortar. The next operation is to prepare the sward on which it is to be spread. This is done by laying upon it a covering of hay, which is trodden down to a level, whereon the peat is spread to the depth of a foot or more. The depth is regulated by means of planks or boards set in parallel lines, and placed, as circumstances may admit, from twelve to thirty feet apart. It is usual to beat down the surface of these beds to give the peat an uniform thickness. After a few days, when the excess of water has, partly by draining off, partly by infiltrating into the soil, and partly by evaporating, disappeared, and the layer of matter has acquired a certain consistence, it is rendered more compact by treading. This part of the work is performed by women and children, who attach flat boards, about six inches broad and twelve to fourteen-long, to their feet. Before this treading is finished, the peat has acquired such solidity that it will bear a person's weight upon it without sinking. The surface is again brought to a level by beating it with oars, shevels, and the like; and after this is accomplished, the surface is divided into squares, the sides of which are about four to five inches. When the tracings thus made are cut, the bricks are about eight inches long by four to five inches square in the section. The drying is performed

by placing alternate rows crosswise upon one another, reversing this order in a few days, and continuing the exposure till the most of the moisture has disappeared. When this is the case, the turf is stored for use, but it is necessary that the moisture be sufficiently expelled before this part of the business is performed, as according to DUMAS, when this is not effected, the stacks are liable to a fermentative process which raises the temperature so high as often to cause spontaneous combustion. It has been already stated, that one essential quality of peat, in relation to its value as a fuel, is its density and freedom from large quantities of mineral matters; but another is also required, namely, that it contains as little water as possible. However well exposed or prepared, air-dried peat always retains from twenty to thirty per cent. of moisture, and this expends a considerable quantity of the heat of combustion in its evaporation. When intended for particular purposes, such as for charring in heaps, for lime-burning, and such like purposes where it is to be piled up in large masses, or has to resist much pressure, the value of the material is enhanced by the quality of strength or solidity, because, if it were very brittle, it would prove almost valueless for either of these uses.

COMPRESSION OF PEAT.—The relative heating power of dense peat well dried is about the same as wood, and half that of coal; the lighter kinds prove to be not more than one-third as effectual as coal for heating. Prepared according to the improved processes which have lately been introduced, it gains considerably in calorific power, as much more combustible material is contained in compressed peat, bulk for bulk, than in the ordinary sods or moulded turf. Much difficulty, however, stands in the way of effecting this condensation of the article, owing to the elastic nature of the fibre, which causes a distention after the force is removed. The system of pressing each sod or mould, as in the preparation of artificial fuels, would never answer with peat, as the labour would be too great in proportion to the value of the material; and, besides, the supply which could be so furnished would be inadequate to the demands of a large consumption. This led Mr. WILLIAMS, a gentleman who has contributed much to the development of the industrial uses of peat in Ireland, to the adoption of powerful hydraulic presses, which, while they are able to overcome the elasticity of the material, can supply it in considerable abundance. It is questionable, however, if his endeavors have been remunerative, as it is difficult to eradicate the preconceived prejudice of manufacturers and traders against this species of fuel. The manner of compressing, as conducted in the Cappoge works, was to break up the fibre of the peat as much as possible after cutting, and then to place it interlaid with coarse cloths or coco-matting under the machine. After the action had been exerted during the period allowed, the material was found to be reduced to one-third its original volume, and to have lost about two-fifths of its weight. In this state, the peat, when thoroughly dried, is not so hygroscopic as when the drying is conducted in the open air and no pressure exerted, and the lighter kinds yield by compression a substance denser than wood; the lower stratum affords a product

still more so. The elimination of the water by pressure improves the quality of the peat in other respects, not the least of which is the reduction of the relative amount of mineral matters contained in it, for considerable quantities are carried off in the water that would remain if it were exposed to spontaneous exsiccation. It would appear that the increased expense of this process is immaterial, when the relative volumes of product it affords, compared with ordinary peat, and the large per centage of water which the latter contains, are considered; for, whereas the latter costs three shillings and sixpence per ton at the bog, the prepared article can be had at five or six shillings. Mr. CORBOLD's method is to convert the peat into a magma, with the addition of water if necessary, and when by means of *centrifugal* power this is subsequently got rid of, a very dense product is obtained. The course recommended by Mr. STONE as described in his patent, sealed in March 1850, is the use of a box divided into a number of compartments suited to the size of the machine, and pressure to be exerted upon this, by rollers adapted to one another by means of leverages. Figs. 38 and 39 are vertical and side views of this arrangement, where the same letters indicate similar parts in each figure. A and B are cast-iron rollers, the latter of which is fixed in a stationary bearing, C. D is an adjusting screw, by means of which the roller may be raised or lowered at

Fig. 38.

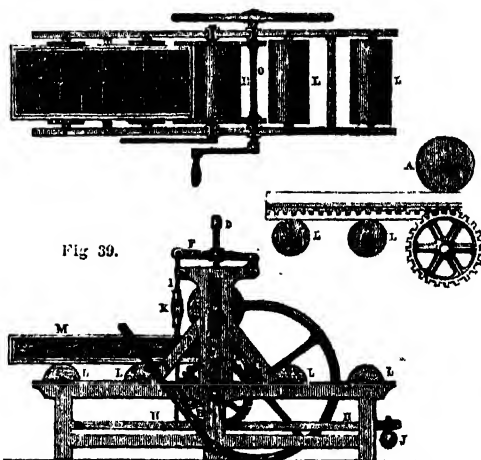


Fig. 39.

pleasure; this screw works in the lever, F, the fulcrum of which is at the top of the side frame, and the handle connected with the long one, H, by the rods, I I, which are adjusted by the screw, K. Pressure is exerted upon the lever, H, by sliding the weight, J. The friction rollers are shown at L L L L, for supporting the pressure box, M, before or after it has passed the pressure rollers, A and B. Upon the shaft of the latter, two toothed wheels, P P, are fixed, which are worked by two pinions, N N, upon the shaft, O; the wheels, P P, gear into two toothed racks at each side of the pressure box, and serve to carry it along under the pressure rollers already indicated.

The box is such that it contains another one, N, in

which the peat is condensed; this is divided into sixteen compartments by means of bevel-edged knives, *a a*, fixed transversely in the cover, and *b b* in the bottom, and so corresponding with one another that when pressure is exerted they are nearly in contact. The longitudinal knife in the middle separates the interior into two divisions.

Motion is given to the whole by means of a winch-handle and fly-wheel appended to the ends of the shaft, *o*; when the motive is steam, the handle is substituted by a drum on which a strap works. The lever, *h*, may be lifted by means of another lever shown in the figure, so as to remove all pressure. The method of operating with this machine is to fill the movable box with peat, after which it is placed inside the box, *m*; the lever, *h*, is raised, and the box is drawn forward by putting the shaft, *o*, in motion. When it has come under the roller, *u* is let down so as to bring *A* in contact with the lid of the box. From the time that the verge of the box has entered under the roller till it has passed the centre, the lid is in an inclined position, varying from an angle of 10° or 15°. At the time the roller is at the centre, the cover will have assumed a horizontal position, and a uniform pressure will be enforced upon the entire contents. When the box has passed through the roller, the lid is taken off, and the compressed material removed and exposed to thorough desiccation. The compartment is again filled, the cover fitted on, and, by reversing the motion of the handle, the box is made to pass the same way backwards. Thus the compressed material is discharged at each end of the machine.

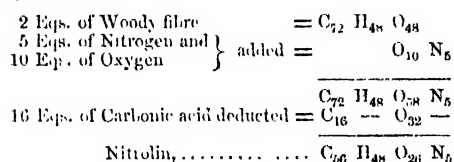
These and a few others are the means hitherto proposed for improving the quality of peat fuel, so as to remove its characteristic fault, namely, want of density; but it seems that as yet the processes have not been conducted with sufficient spirit, or the outlay in machinery is too great in proportion to the value of the material operated upon. It appears that in Ireland the chief improvement in this process must, for some time to come, turn upon the system of drying under sheds, so as to protect the peat from the influence of the rain, a considerable quantity of which it is capable of absorbing, and yet will appear dry to the touch. The amount of water thus retained considerably diminishes the heating power of the turf. This will be seen more clearly from the following data:—When a pound of pure dry peat is burned, and the entire amount of caloric which it yields is conducted through water, it will be found that six times its weight of this liquid will be raised to 212°. In ordinary turf the fourth part of the weight is water, so that there is only three-fourths available as a heating medium. Were a pound of this consumed in the same manner as the foregoing, it is evident the caloric developed would raise only four pounds and a half to the boiling point. This quantity would, of course, evaporate the water contained in the peat, so that the visible effect would be as four and a quarter to six, or about thirty per cent. in favor of the dried material. Such a wide difference, it is needless to say, is sufficient cause for condemning the moist material even for domestic use, but especially in manufactories, where it is an object of

the first importance that the fuel should exert the greatest possible effect in proportion to its bulk and value.

Before passing to the discussion of the action of heat upon peat, it will be well to devote a little attention to the consideration of the nature of those substances contained in it, as well as those which are artificially produced from it. It has been stated already—page 51—that by the action of alkalies upon peat, the greater part is dissolved, and that, when the liquor is further treated with acids, the *ulmin* is precipitated in flakes. This substance, which is the principal and most important component of peat in its ordinary state, is so analogous to woody fibre in its composition, that the changes which the material producing it has undergone, may be considered as sufficient to account for the difference. By the researches of BRACONNOT and others, it has been proved that in the fresh peat *ulmin* is combined with lime, and forms therewith a true chemical compound—ulminate of lime. Ulmin or humus, popularly termed vegetal mould, has the following composition when prepared from wood and sugar:

	From Wood.	From Sugar.
Carbon,.....	72.7	65.65
Hydrogen,.....	6.1	4.28
Oxygen,.....	21.2	30.07
	100.0	100.00

When peat is subjected to destructive distillation ammonia is invariably one of the products, a circumstance for which it is difficult to account, seeing that ulmin is entirely devoid of nitrogen, unless it be admitted that, during the progressive decomposition of that body, nitrogen is assimilated from the air, just in the same manner as decaying wood or vegetal matter takes up the same element. In the course of the decomposition of vegetal bodies, oxygen and nitrogen are absorbed and combined with the other elements, and the consequence is the formation of a new substance called by HERMANN *nitrolin*—a body that approximates closely in its composition to animal flesh. Such a metamorphosis may be explained by supposing that two equivalents of woody fibre take five equivalents of nitrogen and ten of oxygen from the atmosphere, and give off sixteen equivalents of carbonic acid; thus—



By a further change these elements are disturbed, and carbonic acid is produced together with ammonia. Besides these, several other new substances of a brown or black color remain, among which are ulmic acid, *et cetera*. DUMAS supposes that the ammonia results from the decomposition of animal remains embedded in the marshes; but the Editor is of opinion that it is mostly derived from the atmosphere.

When peat is exposed to the action of heat in close vessels, it affords a variety of substances, the principal being pyroligneous acid; a brown empyreumatic crystallizable oil, from which numerous products may be

extracted, and among them paraffin; carbonic oxide and carbonic acid, hydrocarbon gases, together with a variable quantity of ammonia. Industrial progress has invested several of these with a new value during the last few years, so much so that they have become special objects of manufacture. This has been shown under the heads ACETIC ACID, AMMONIA, ASPHALT, CANDLES, *et cetera*; and with regard to certain inflammable gases and other bodies, their importance will appear further on. The products of the distillation of peat are all useful in the arts, and consequently are in constant request. To provide them in sufficient quantity, or at least in some degree to supply the wants of the trades using them, a manufactory was erected a few years ago near the town of Athy, in Kildare, Ireland, for the purpose of distilling peat, and obtaining the useful products which it affords. This manufactory has now established itself, although it had many difficulties to contend against. It is worked on the principle of Mr. REES REECE's patent, sealed in 1849. The idea was derived from the application of inflammable gases to heating purposes by the late M. EBELMEN, for the utilization of inferior coals and other combustibles, by converting them into gases, the object being the production of those organic bodies already alluded to. These are produced in greater abundance from peat than from other combustibles, owing to the large amount of water in it, which keeps the temperature low during the distillation, and thus favors the formation of such products. The principle of the distillation is the introduction of a blast of air at the bottom of a furnace filled with the combustible. The heat developed in this part passing up with the gases through the mass, causes the destructive distillation of the latter, and the expulsion of the empyreumatic products with the combustible and other gases from the fire. By proper contrivances these are operated upon, in such a way that all the condensable substances are removed, and the inflammable products which cannot be liquefied are employed to heat boilers, stills, or evaporating pans required in the purification of the crude products. It is this application of all the products to economical purposes which renders the manufactory so novel in its nature, for the very substance operated upon is made to supply all the requisites for carrying out the manufacture, besides supplying the useful products.

For the following important details with reference to this manufactory, the Editor is indebted to the *Journal of Industrial Progress*, by Professor SULLIVAN:—

From repeated examinations of peat with reference to the amount of tar, oils, paraffin, and ammoniacal

salts which it yields, as well as from the researches of the patentee, most flattering results were anticipated from the development of this branch of industry. To carry it out, a company was organized, called the IRISH PEAT COMPANY, which stated in its prospectus that, by a manufactory capable of operating on one hundred tons daily, or thirty-six thousand five hundred tons annually, the following commercial results would be attained; namely,—

EXPENDITURE.

36,500 tons peat, at 2s. per ton,	£3,650
455 tons of sulphuric acid, at £7 per ton,	3,185
Wear and tear of apparatus, <i>et cetera</i> ,	700
Wages, labor, <i>et cetera</i> ,	2,000
Freight and incidental charges,	2,182
	£11,717

PRODUCE.

365 tons of sulphate of ammonia, at £12 per ton,	£4,380
255 tons of acetate of lime, at £14,	3,570
19,000 gallons of naphtha, at 5s.,	4,750
109,500 pounds of paraffin, at 1s.,	5,475
73,000 gallons of volatile oil, at 1s.,	3,650
36,000 gallons of fixed oil, at 1s.,	1,800
	23,625

leaving a net profit of £11,908, or a fraction more than a hundred per cent. The cost of the manufactory for working such a quantity was stated to be about ten thousand pounds. That peat, and other substances heretofore useless, should be productive of a trade so profitable, was more than could well be credited by the parties wishing to embark in the speculation; and to satisfy themselves on this point, a series of experiments was instituted in the laboratories of the Museum of Irish Industry, under the superintendence of Sir ROBERT KANE and Professor SULLIVAN. These were conducted upon specimens of peat from various peat deposits in Ireland in a twofold manner: firstly, by distilling the peat in close vessels, and secondly, by effecting the distillation by a combustion of a part of the material with a blast of air, as proposed in the manufactory.

In operating by the former method, a retort was used similar to that employed in the distillation of coal in the manufacture of gas. To the exit pipe from this retort a series of Woulfe's bottles were adapted, wherein the greater portion of the tar and other aqueous products were deposited, the remainder being condensed in a worm fixed in a barrel of water, and the permanent gases collected. In each trial one hundred-weight of peat was worked off in eight to fourteen charges, according to the density of the substance. The annexed table represents the quantity of the gross products obtained:—

No of Experiments	Locality whence obtained	Water.	Tar.	Charcoal	Gas.
1.	Surface peat, } A mixture of about equal parts of the two peats, from }	23-600	2-000	37-500	36-900
2.	Dense peat, } Mount Lucas Bog, near Phillipstown,	32-273	3-577	39-132	25-018
3.	Light surface peat, from Wood of Allen,	38-102	2-767	42-642	26-489
4.	Black compact peat, from do.,	38-628	2-916	41-110	32-346
5.	Surface peat, from Ticknevin,	32-038	2-844	23-437	42-121
6.	Do. distilled with the retort heated to a very bright redness,	38-127	4-417	21-873	35-693
7.	Surface peat, from Shaunon,	21-183	1-462	18-973	57-746
	Dense peat, from do.,				
	Average,	31-378	2-787	29-222	36-616

The amount of ammonia, acetic acid, and naphtha, as well as that of the oil and paraffin in the tar; the following table contains the results obtained:—

TABLE REPRESENTING THE PER CENTAGE OF AMMONIA, NAPHTHA, ACETIC ACID, PARAFFIN, AND OILS, OBTAINED BY THE DISTILLATION OF PEAT.

Locality whence obtained.	Ammonia.		Acetic Acid		Pyroxylic spirit or naphtha.	Paraffin.	Volatile oil.	Fixed oil.
	Ammonia as NH_3	Corresponding quantity of sulphate.	Acetic acid as $\text{C}_2\text{H}_3\text{O}_2$ HO.	Corresponding quantity of acetate of lime.				
1. Surface peat, { A mixture of equal parts } 2. Dense peat, { of both peats from Mount } { Lucas Bog, Philipstown, }	0.302	1.171	0.076	0.111	0.092	0.024	0.684	0.469
3. Light surface peat, Wood of Allen,.....	0.187	0.725	0.206	0.302	0.171	0.179	0.721	0.760
4. Black compact peat, do.,.....	0.393	1.524	0.286	0.419	0.197	0.075	0.571	0.565
5. { Surface peat, from Ticknevin,..... } { Do. distilled with the retort,..... } { heated to redness,..... }	0.210	0.814	0.196	0.287	0.147	0.170	1.262	0.617
6. Surface peat, from Shannon,.....	0.195	0.756	0.208	0.305	0.161	0.196	0.816	0.493
7. Dense peat, do.	0.404	1.567	0.205	0.299	0.132	0.181	0.829	0.680
	0.181	0.702	0.161	0.236	0.119	0.112	0.647	0.266
Average,	0.268	1.037	0.191	0.280	0.146	0.134	0.790	0.550

In the second series of experiments, in which the peat was consumed by igniting it, and then supporting the combustion by a blast, the same peats were used as in the foregoing tables. The annexed table shows, however, only the products obtained from those which in the former experiments exhibited the greatest dissimilarity, this being sufficient for the purpose of comparison:—

Character of Turf, and Locality whence obtained	Water.	Tar.	Ash.	Gases.
Light surface peat, from Wood of Allen,	31.678	2.510	2.493	63.319
Dense peat, do.	30.663	2.395	7.226	59.716
Dense peat, from the River Shannon,.....	29.818	2.270	2.871	65.041

The amount of ammonia, acetic acid, naphtha, paraffin, and oils, obtained in the same way, and expressed in the following numbers, affords a comparative view of the merits of both methods of working:—

TABLE REPRESENTING THE PER CENTAGE OF AMMONIA, ACETIC ACID, NAPHTHA, PARAFFIN, AND OILS, OBTAINED BY THE DISTILLATION OF PEAT IN A BLAST OF AIR.

	Ammonia	Acetic acid	Naphtha	Paraffin.	Oils.
Light surface peat, Wood of Allen,.....	0.322	0.179	0.158	0.169	1.220
Dense peat, do.,.....	0.344	0.268	0.156	0.086	0.946
Dense peat, from the River Shannon,	0.194	0.171	0.106	0.119	1.012
Average,.....	0.287	0.207	0.140	0.125	1.059

The average results of both methods of operation gave for the distillation in close vessels—

	Average	Maximum	Minimum
Aqueous products, 30.614	32.678	29.818	
Tar, 2.392	2.510	2.270	
Gases, 62.392	65.041	59.716	
Ashes, 4.197	7.226	2.493	

The watery products and tar afforded—

	Average	Maximum	Minimum
Ammonia,.....	0.287	0.344	0.194
or as			
Sulphate of ammonia, 1.110	1.330	0.745	
Acetic acid,.....	0.207	0.268	0.174
or as			
Acetate of lime,.....	0.305	0.393	0.256
Naphtha,.....	0.140	0.158	0.106
Volatile and fixed oils, 1.059	1.220	0.946	
Paraffin,.....	0.125	0.169	0.086

Placing these numbers in apposition, the following will express the relative value of the two modes:—

	Average produce from close distillation.	Average produce from distillation in blast of air.
Ammonia,	0.268	0.287
or as		
Sulphate of ammonia, ..	1.037	1.110
Acetic acid,.....	0.191	0.207
or as		
Acetate of lime, ..	0.280	0.305
Naphtha, ..	0.146	0.140
Oils,.....	1.310	1.059
Paraffin,.....	0.134	0.125

The similarity of these numbers shows that very little difference exists between the results obtained from the distillation of the substance in close vessels, and from its decomposition in the fire by a blast of air. In the first case, however, there remains an average of twenty-nine parts of charcoal, which might determine a preference for that method, were it not that the greater part of this is consumed in carbonizing the matter in the retort.

A similar and independent series of experiments was conducted by Dr. HONGES, whose results are appended

below, and contrasted with those arrived at by Professors KANE and SULLIVAN, as well as with those form-

ing the basis upon which the company's prospectus was founded:—

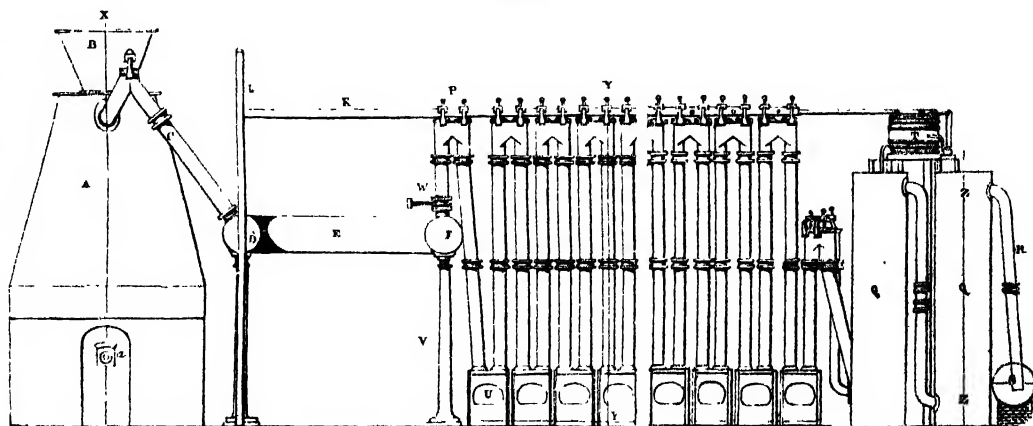
	Kane and Sullivan.		Hodges.		Statement in Company's Prospectus	
	Per ton	Per cent	Per ton.	Per cent	Per ton.	Per cent.
Sulphate of ammonia,.....	21 $\frac{3}{4}$ lbs.	1.110	22 $\frac{3}{4}$ lbs.	1.000	22 $\frac{3}{4}$ lbs.	1.000
Acetic acid—real hydrated,....	4 $\frac{1}{2}$ " "	0.207	7 $\frac{1}{2}$ " "	0.328	— " "	—
or as						
Acetate of lime,.....	6 $\frac{1}{2}$ " "	0.305	— " "	—	nearly 15 $\frac{7}{10}$ " "	0.700
Wood naphtha,	50 $\frac{1}{2}$ ozs.	0.140	83 $\frac{1}{2}$ ozs.	0.232	66 $\frac{3}{8}$ ozs.	0.185
Tar,.....	53 $\frac{1}{2}$ lbs.	2.390	99 $\frac{1}{2}$ lbs.	4.440	—	—
Products of {Paraffin,.....	2 $\frac{1}{2}$ " "	0.125	—	—	3 lbs.	0.104
the tar, {Oils,.....	nearly 2 $\frac{1}{2}$ galls.	0.159	—	—	2 $\frac{1}{2}$ galls.	0.071

If the difference of the peat in these experiments be taken into account, the results of the three columns will be nearly equal; for in HODGES' experiments the peat was of a black unctuous nature, weighing, per cubic yard, from five and a half to six and a half hundred-weight.

At first, the apparatus erected for the distillation, *et cetera*, was on a small scale, and not so much with the object of realizing an immediate profit, as with a view to the perfection of the process by which the operation might be conducted on a scale of greater magnitude. During this preliminary phase of the undertaking, very little advantage accrued beyond opening the eyes of the conductors to the necessity of having some more perfect medium for condensation, and turning the inflammable gases to useful purposes, as also for purifying the products, and bringing them into marketable condition. It was necessary, therefore, under these circumstances, to erect new works; and, as many things had to be invented, this occupied considerable time. The factory has now been in active operation for some few years. The arrangement for the combustion of the peat consists of four furnaces, constructed like ordinary blast furnaces, and without gratings, but furnished with three tuyeres through which the blast enters. Each furnace is thirty-two feet seven inches high, from the ground to the top of the hopper; the hearth is three feet two inches deep, three feet wide, and eighteen

inches to the top of the dam-plate; the tympan is thirteen inches high, and has two inches of water space; the boshes are seven feet six inches high from the bottom of the crucible part, and twelve feet wide at the belly; the cone or body is sixteen feet high, and six feet wide at the tunnel head. The base of each furnace is square as high as the belly, and the whole of the cone or body is covered with boiler-plate firmly riveted. Such a protection is necessary, in order to prevent a leakage of the products of distillation, besides giving greater stability to the erection. The top of each furnace is completely closed by a conical valve three feet in diameter, and surmounted with a changing hopper provided with two tight-fitting lids. This hopper is five feet high from the valve-opening to the lid, and eight feet in diameter at the top. Two pipes, each twelve inches in diameter, convey the products of distillation into an hydraulic main, three feet in diameter, whence the condensed tar and other liquids flow into a tank, while the gases are made to pass through two double rows of upright condensing pipes, twelve inches in diameter, and twenty-five feet high, including two series of rectangular boxes upon which they are fixed. During the passage of the elastic vapors and gases through these pipes, an additional quantity of tar and aqueous products is liquefied and collected in rectangular boxes placed in connection with the pipes, by an arrangement which will be further explained in the drawings annexed. After

FIG. 40.



the gases traverse the condensers, they are conducted through a series of eight scrubbers, twenty feet high, and arranged in four rows. Each scrubber has three layers of small stones resting upon gratings, and is besides fur-

nished with a mill and tumbler, by which a dense shower is made to fall through the scrubber. By this contrivance the gases are washed of all traces of tar and condensable matters, such as naphtha, *et cetera*. From the

scrubbers the gas flows into a kind of main called the trunk, twenty-five feet three inches in length, and three feet eight inches in diameter, and from which it is distributed to the several fire-places to be consumed under evaporating pans or boilers, as required.

Fig. 40 is a side elevation of this arrangement, represented, for want of space, as broken off in the middle. A is one of the four furnaces, a section of which, along the line x, is shown in Fig. 41; and Fig. 42 is a plan of the platform, G, on the top of the furnaces, with part of the condensing apparatus attached. The same letters in each of the figures indicate corresponding parts.

Referring, in the first place, to the sectional view of the furnace—Fig. 41—a represents the arrangement of the tuyeres, with their nozzles, showing the water spaces and the plug valves for allowing the

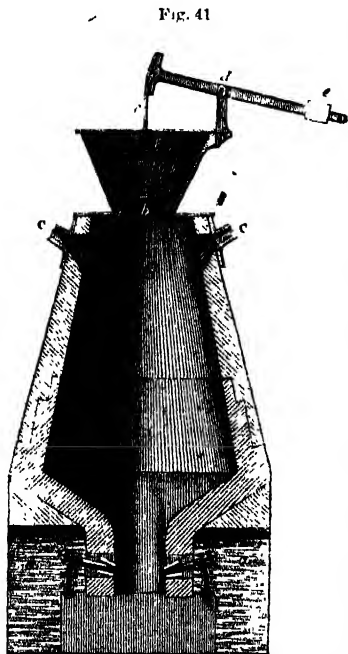


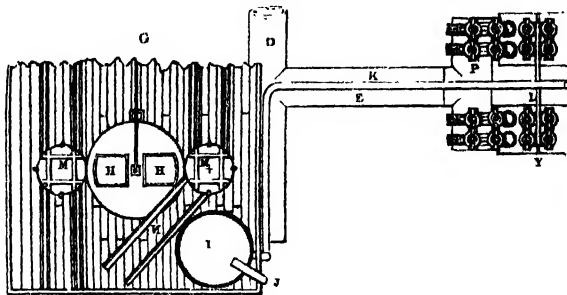
Fig. 41

of cast-iron or other material to form the counterpoise.

The platform on the top of the four furnaces, part of which is represented at G, in Fig. 42, is constructed of planks of wood laid on the same plane as the covers of the hoppers. The dried peat or turf is elevated to this platform in iron waggons, each thirty cubic feet in capacity, by means of a water lift, consisting of a floor upon which four waggons fit, supported by a frame or cage with friction pulleys at the angles, for working against the four upright pillars of wood which support a framework at top, having a drum and brake. The flooring of the cage is attached to a chain which passes over the forementioned drum, and is counterpoised by a wrought-iron cistern, five feet square, and two feet six inches deep, provided with a valve in the bottom, with an externally projecting spindle. The peat is brought from the bog in flat-bottomed boats by the canal, which

terminates in a kind of basin, having a quay a few yards wide at the foot of the lift. Here the waggons are

Fig. 42.



filled with the turf, and they are then rolled in upon the floor of the cage previously let down to receive them. In this position of the cage, the counterpoise or cistern is at the top, and, while there, water is allowed to flow into it from the tank, I, which is in turn supplied by the feed-pipe, J, connected to a large pump worked by a steam-engine which drives the other smaller ones throughout the works. When the cistern is full, it more than counterbalances the weight of the cage and loaded waggons; and, accordingly, on letting go the brake, the former descends, and by means of the chain passing over the drum, draws up the cage and waggons to the level of the platform, G. When the cistern full of water reaches the ground, the projecting pin strikes against it, by which the valve is lifted, and the water allowed to flow out. The waggons full of turf are next rolled along tramways at each side of the hoppers, one of which is shown at N, to the furnace into which it is discharged. This part of the work is performed by rolling the waggon on to a turning table, M, situate at each side of the furnace, and there made to perform a fourth of a revolution, so as to bring the end of the waggon, which is provided with a hinge and latch, over one of the hopper lids, H; the latter is opened, and the turf discharged into the orifice. Three waggons full, or ninety cubic feet, fill the hopper, and this constitutes a charge. Whilst the hopper is being filled, the conical valve, b, is raised to the position in which it closes the furnace, as shown in Fig. 41, and none of the products of distillation can escape; but as soon as the hopper is filled, the lids, H H, are firmly closed, and the grooves into which the lid flanges are partly filled with turf dust and some of the blue clay marl underlying the peat bog, mixed up into a magma with water. This paste forms an excellent lute round the lid, which is kept tight by a latch.

The valve, b, Fig. 41, may now be lowered by the lever, d, which, while the valve is up, has its extremity bearing the counterpoise, e, hooked to the platform by means of the small aperture seen near the counterpoise; but when this is unhooked, the valve descends, and the turf falls into the furnace. This being effected, the lever is again hooked in the usual position, and the hopper recharged. In this method of working, the only loss sustained is merely the full

of the hopper of gases each time the furnace is charged. When light peat is burned, the charge weighs about seven hundredweight, so that it would require about a hundred and forty-three charges to burn fifty tons of material, and two hundred and eighty-six to burn one hundred tons, the work assigned to each furnace in twenty-four hours. Allowing one hundred cubic feet of gas to be lost at each charge, the total for each furnace during the day's working would amount to twenty-eight thousand six hundred cubic feet; but this is too high, for the average weight of a charge of the brown turf employed is about half a ton, and, therefore, only two hundred charges are required to perform the work, so that the loss is reduced in actual practice to twenty thousand cubic feet; and this quantity, compared to the total quantity produced, is very insignificant.

When the fire is lighted in the furnace, and the blast directed upon it, the part immediately ignited is resolved into the simplest and most permanent products of combustion; but as these ascend, the carbonic acid is resolved into carbonic oxide by the incandescent fuel overhead, and this gas, together with the nitrogen of the air, rises in a heated state through the mass. These superheated gases are the agents which effect the distillation of the great mass of peat in the body of the furnace, and carry the products off to the mains, as already intimated, by outlet pipes, *c*—Figs. 40 and 41—of which there are two to each furnace. These outlets are fixed near the top of the furnace; they consist of a short ascending and a long descending pipe, the angle where they meet being provided with a hand-hole for cleaning out, and which can be secured by a dog and screw. The long arm enters the hydraulic main, *D*, shown in section in Fig. 40, and represented as broken off in the plan, Fig. 42. This main is kept half full of liquid, below the surface of which the outlet pipes dip. Each furnace is thus isolated in the same way as the retorts in a gas factory. The hydraulic main consists, properly speaking, of two; the principal one running along the furnaces in front, and marked *D*; and, secondly, a cross piece, *E*, which connects the former to a shorter one, *F*. Both these are closed at the ends with plates of iron, which can be removed whenever they want cleaning. Overflow pipes, screwed to those plates, draw away all the tar and liquid which accumulate in the mains above the proper level; this excess is conveyed into a tank not marked on the drawings, but its place is indicated by *Y*, in Fig. 42. Four ascending pipes convey the gas from the main into the condensers; each of these pipes is provided with a valve, *w*. As was already stated, there are two distinct series of condensers, each consisting of eighteen rectangular boxes, shown in section at *U*, Fig. 43. Upon the top of each of these are placed four upright pipes, and those of each series constitute two rows. The adjoining pipes in each row, belonging to different boxes, are connected by a breeches-piece, which has two openings in the top, closed by caps, dogs, and screws, *r*. The gas flowing through the valve, *w*, is thus enabled to ascend one pipe in a row and down the next, into the first rectangular box, thence up the next, and, by means of the breeches-pipe, into the adjoining condenser pipe and box, and so

on. A diaphragm, as seen in Fig. 43, separates the box into two compartments; this division is not perfect, however, for at the bottom a space is left, so that both form only one.

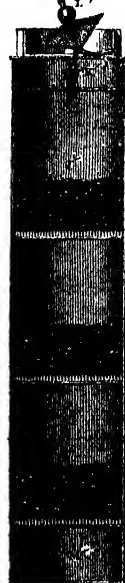
The four pipes open into one compartment, and as both are kept nearly half full of water, the gas entering into the side compartment cannot escape otherwise than by the pipes, unless the pressure is so very great as to force all the liquor out by *v*, into the next chamber. All the condensable matter that accumulates in the inner chamber soon finds its level in the outer one by the communication at the bottom of the box, and when it rises to a certain height in the latter, it flows out by a siphon pipe into a conduit in connection with the tank, *v*. All the boxes are in communication with one another by a short connecting pipe passing from one to the other near the bottom; the same level of liquid is thus insured in all. To prevent the condensing pipes ever getting too hot, a conduit, *K*—Fig. 42—in connection with the cistern, *t*, is carried along the top between the two rows, to each set of which it sends out an arm, *L*, pierced with small holes, which allow a fine stream of water to fall on the tops of the pipes, and to trickle down the sides, and thus cool them effectually.

Notwithstanding all the refrigerating surface afforded by the double line of condensers, a certain quantity of tar and ammonia, and the greater part of the naphtha, still remain uncondensed, and are carried forward mechanically by the force of the blast; and to guard against a loss being sustained, the scrubbers, *Q*—Fig. 40—have been appended. These are arranged in four rows, corresponding to the four rows of condensing pipes. Each scrubber consists of a cylinder of wrought-iron, four feet six inches in diameter, and twenty feet high, closed at both ends, and having three gratings in the interior, upon each of which is placed a layer of stones, shown at *j*, Fig. 44. The gas enters at *M'*, and passes up through the layers of stones, while, at the same time, the mill, *K'*, supplied with water from an inch pipe connected with *K*, Fig. 42, or with the tumbler, *L'*, produces a dense rain by its revolution; and this shower meeting the gaseous bodies ascending through the layers of stones, completely removes all the considerable bodies remaining in it. The water which thus traverses the scrubber, and becomes partly saturated with tar, ammoniacal matter, and naphtha, flows off from the base by a pipe into a tank, not exhibited in the drawing, but which may be designated by *z*, Fig. 40. After passing through the first scrubbers,

Fig. 43.



Fig. 44.



the gas enters the second series by means of a pipe, and after it is washed in these, as described, it flows into a kind of gasometer, *s*, Fig. 40, consisting of a pipe twenty-five feet three inches long, and three feet eight inches wide, and kept full of water to the level of the line shown. By means of the valve, *w*, in the main, *F*, and the dip of the pipe, *R*, into the water of the gas-holder or trunk, *s*, each row of condensers, and each pair of scrubbers, may be isolated, and the gas shut off from them whenever they require cleaning.

As the whole of the water which passes through the scrubbers must be distilled in order to obtain the ammonia and naphtha which it has absorbed, it is found desirable to make the same liquid serve two or three times for washing the gas. This is done by placing barrels, *T*, on the tops of the scrubbers, *Q Q*, and pumping into them from time to time a portion of the liquor from the tank, *Z*. Each barrel supplies liquor to four scrubbers, by means of branching pipes.

Owing to the retention of the tar by the layer of stones, the scrubbers would get clogged from it, were there no provision made for cleansing them. The means adopted is to inject steam into them once in the day, by which the tar is melted, and in this state flows out at the bottom of the tank. From *s* the combustible gases are carried off by a duct, from which, by other channels, it is taken to the several flame-beds, where it is consumed.

Such are the principal details of this manufactory, having in view the recovery of the volatile products of distillation only, the charcoal which the peat would afford being entirely burned.

The high heating power of peat-charcoal, as well as its disinfecting and other qualities, invest it with peculiar interest to the smelter, the sanitary reformer, and the agriculturist: for the former it has long been productive of great advantages, more especially in the manufacture of iron, and therefore its production, on the most economical scale, and in the largest quantity, has been a subject to which some attention has been paid. This is more particularly the case in Bohemia, Bavaria, France, Russia, and other countries, where it is used in the blast-furnaces of their iron-smelting establishments, and produces very satisfactory results. In the numerous other processes to which the metal is subjected, the charcoal is found quite as efficient, if not more so, than wood-charcoal. In England, however, where coal is so abundant, a material which is at her command in as great abundance as her coal, has been allowed hitherto to remain useless; but it is to be hoped, that the success which has attended its application in the particular instances alluded to, and the free discussion of its advantages which one now meets with, will remove any prejudices existing in the minds of manufacturers against its employment. At present, or at least till within a recent period, the cost of the product has been very high, in fact out of all proportion when compared to that of other kinds of fuel; and this, perhaps, has been one cause why it has not been extensively consumed in smelting and other works: but if, by the attention of manufacturers, the charring of peat had been understood, and conducted on such a scale as would bring its marketable value on a footing

with that of coke, there is little doubt of its very soon being introduced into several establishments from which it is at present excluded. When peat is acted upon by heat in close vessels, it yields a variable amount of charcoal, from twenty-five to forty per cent., according to its density and state of dryness; but, as it is rarely distilled in this way, the quantity obtained is from twenty-five to thirty per cent., and at best does not exceed thirty-five per cent. The methods followed for the charring of peat are, in some respects, similar to those already described as being pursued in carbonizing wood on the large scale; these are the meiler system, and that by the furnace. For operations by the first of these methods, the nature of the peat and the regular form of the sods or bricks offer advantages for constructing the heap more regularly, leaving less interstitial space than the logs of wood, and, being less combustible than the latter, the process does not exact that minute attention which the carbonization of wood requires. It is necessary that the peat should be thoroughly desiccated, otherwise the charring will proceed irregularly, and sometimes not at all. Large quantities of peat are carbonized in this way in the Vosges, in Bavaria, Saxony, and Bohemia. In these places, one or other of two forms of constructing the meiler is adopted—either the circular or bee-hive, so frequently resorted to in charring wood, or the rectangular one. At the Royal Iron Works of Weierhammer, in Bavaria, where the refining and puddling of iron has been carried on since 1838 by means of peat-charcoal, the peat is charred in the circular mound, prepared almost as in manufacturing wood-charcoal.

A level site being chosen, a stake or quandel is fixed in the middle of a circular space, and round it on the ground a quantity of brushwood is spread, and which in turn is covered with waste charcoal from a previous operation. The turf is then piled round to the extent of the base, and to the proper height, preserving the conical shape. Generally, the size of the heap is about two thousand five hundred cubic feet, or thirteen and a half tons of the peat of the locality. When the central stake is withdrawn, brushwood is introduced into the opening and ignited. This communicates fire to the surrounding mass, which, in turn, conveys the heat towards the exterior. Owing to the closeness with which the turf admits of being packed together, the carbonization would proceed but slowly, were it not that air-channels of the breadth of a single brick of the peat are constructed at regular distances, and radiating to the circumference of the meiler. A covering of moss and leaves is placed upon the body of the heap, and outside this another of sand and turf ashes, or charcoal dust, is thrown on, leaving the upper part open, as a kind of chimney for the passage of the gaseous products, till the mass has been thoroughly ignited. As soon as flame appears at the top of the heap, a covering is thrown on, and the contraction of the mass observed, so as to keep any breaks occasioned by the sinking renovated. The charring is conducted regularly in the whole meiler by closing the draught-holes at the base, where the combustion becomes too vivid, or boring a few about a foot asunder in the upper part, where the progress is slack. Twelve to fourteen

days are necessary to char and cool a moiler of the above size, so as to be fit for removal. About seven hundred cubic feet of charcoal are obtained, weighing about three tons eight hundredweight, or 27.7 per cent.; hence, somewhat less than four tons of the peat of the district yields one ton of charcoal.

In Saxony, the rick or rectangular system is adopted, and the results are good. The ground is levelled and covered with sand in the usual way, and afterwards the rectangular space marked out; this is about fifty feet long by five or six in breadth. The middle of this plot is hollowed out into a kind of basin, and from it two channels or drains are cut from the ends of the intended heap, but inclining towards the central cavity. Both channels and well are constructed of, or are lined with bricks, a layer of clay being laid beneath, so as to prevent any fluid products collecting therein from percolating through the soil. A small gutter leads from the cavity in the middle to a tank at a little distance, where the liquids are recovered. These necessary constructions being made, a number of quandels is fixed in the longitudinal channel, ten feet apart, and the peat heap constructed to the height of four feet, leaving transverse channels corresponding with the vertical one which the stake forms. When finished, the quandels are withdrawn, and the whole coated with a mixture of clay, sand, and chopped straw or grass, the latter being used to prevent the luting from cracking. This mixture is prepared in two boxes or pits, one at each side of the mound, and quantities of it are always at hand so as to be available for stopping any cracks which might present themselves during the charring. Ignition is commenced at each end of the rhomboid by a fire placed in the central channel; the brushwood with which this has been filled burns, and, in doing so, sets fire to the surrounding peat. When the turf is fully ignited throughout the whole mass, a thick black smoke issues from the chimneys; as the carbonization proceeds, this becomes lighter, assuming gradually a greyish-white color, and finally changes to a bluish shade as the moisture evaporates. At this state, sulphurous acid becomes disengaged. As soon as the whole of the moisture is dispelled—a fact ascertained by holding the hand in the vapor as it issues from the chimneys, and observing if condensation takes place—the fire is gradually smothered by closing the air channels and fire flues. Care is also required in the management of the draught, so as not to allow of a consumption of charcoal taking place; generally, the apertures on the windward side are kept closed, the opposite ones being sufficient to supply air. The charcoal prepared in this way is of excellent quality, and much used in the metallurgical establishments of Saxony and Bohemia.

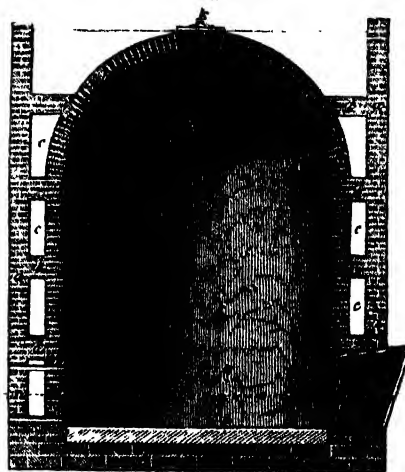
Both these systems of charring peat afford nearly the same yield of charcoal, when the operations have been properly attended to. It ranges from twenty-four per cent. by weight and twenty-seven by bulk when the peat is not thoroughly air-dried; but if this condition has been attained, the product is about twenty-seven per cent. by weight, or thirty-two and a half by bulk: a larger produce is occasionally obtained, but in those cases the exception must be attributed to the density and dry-

ness of the material before carbonization. The cost of a ton of charcoal at Weierhammer, manufactured by the process described, is about sixteen shillings and twopence, the peat from which it is produced having a marketable value of two shillings and elevenpence halfpenny per ton: allowing that four tons of peat are required for the production of one ton of charcoal, it appears that the charring expenses for one ton of charcoal are about four shillings and fourpence. In the neighborhood of Carolinen Hütte, near Achthal, in Styria, where some successful attempts have been made to smelt iron with peat in its raw state, mixed with wood, a ton of peat-charcoal costs twenty-two shillings and sixpence; but of this, eighteen shillings and twopence form the cost of the material, so that, practically, the charring expenses are the same as at Weierhammer. Such is also the cost of carbonizing by the moiler or rick system in Saxony.

Partly from the fact that less labor is required in managing the operation, whilst a regularity in the produce is, in some measure, insured, and partly from the circumstance that there always exists a supply of material at hand in every peat district, which would render the expense of removal of furnaces unnecessary when once erected, the system of charring in kilns has been resorted to with advantage. Furnaces or kilns are employed near Meaux in France, in East Friesland, and Bohemia, to a considerable extent.

The furnace or kiln employed for this purpose at Oberndorf, in Wurtemberg, is represented in Fig. 45. It is an upright cylinder, nine feet high and five and a half feet in diameter, having a capacity of about two

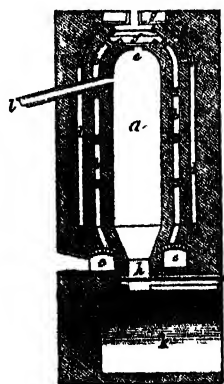
Fig. 45.



hundred cubic feet, and capable of distilling about four tons of average peat; the top is closed by an arch, with the exception of an opening, *i*, through which the peat is introduced; it also answers the purposes of a chimney till the charge is carbonized. A double line of construction is adopted in the erection of these kilns; an inner one, *b b*, of firebrick, and an outer one, *a a*, of more common material: both are about fifteen inches thick, and between them is an interstice, *c c*, of the same width, excepting where the brickwork extends the

whole breadth, as at *d d*, for giving greater firmness to the construction. The superior aperture, *i*, is closed by a tightly-fitting lid, *k*, when necessary; at the base is another door, closed by a cast-iron plate, *f*; and behind this is a space, *m*, formed by the door and the plate or board, *e*, and which is filled with sand through the aperture, *g*; thus the draught is effectually cut off at this orifice. There are three tiers of holes, *d d d*, formed at a short distance from the base of the furnace, through which air enters for supporting the combustion of the peat during the carbonization, as long as this takes place. In working this kiln, the peat is thrown in at the top and packed closely, with the exception of a few channels left free, corresponding to the lower draught holes, and also a vacant space in the centre; after being filled, fire is thrown in from the top, and the orifice in this part left open; when the fire has spread through the mass, so as to present a glowing appearance on being viewed through the lower apertures, these are closed with clay stoppers, and the combustion allowed to proceed till the same appearance is observed on looking through the second holes, when these are likewise stopped; and when the mass appears white hot at the third row of perforations, and no more smoke appears, all the apertures are secured, and the mass is allowed to remain till cold. Forty-eight hours are occupied in bringing the mass to incandescence, and after that seven or eight days are required for the cooling of the furnace. To avoid this delay, it is customary to have a damper plate situated in the bottom of the furnace, under which is a pit, so that, on withdrawing the damper, the red-hot charcoal falls into the pit, and the furnace is ready for a fresh charge. Sometimes the furnace is so constructed as to enable the manufacturer to recover some of the products of distillation, and use the combustible products for heating the mass of peat. In these, a pipe leads from the shoulder of the arch to a kind of condenser, where the ammoniacal and tarry matters are retained, and the gaseous bodies are reconducted by pipes to the bottom of the furnace, where they are burned under a grating, and serve to ignite the charge. No delay, or at most

Fig. 46.



only an inconsiderable one, takes place in the charring with the latter kind of furnace, and the product is satisfactory in relation to quality and yield. Of this description are the kilns used at Crouy-sur-l'Ourocq, near Meaux, one of which is represented in Fig. 46. In this kiln the carbonization is effected in a cylinder, *a*, heated exteriorly by the flame and heat from the fires, *c c*, which circulate in the spiral flue, *b b*; *d d* is a chamber, encircling the walls of the flue, wherein air is confined, with the view of retaining and equalizing the heat. The peat is introduced into the kiln by the aperture, *e*, at the top; this aperture is closed when

the charring is going on, by an iron plate, *f*; the products of the combustion going on in the fires, *c c*, issue by an opening, *g*, in the top, and those of the distillation of the charge by a pipe, *l*, connected with a condensing apparatus of the usual construction, and in which the liquid products are retained, the uncondensed gas being conveyed back to the fires, where by their combustion they serve, in part, to maintain the proper degree of heat. When the carbonization is completed, the charcoal is removed by the channel, *h*, by drawing the plate, *i*, which serves as the bottom of the kilns; it then falls into the chamber, where it is allowed to cool; from thirty-five to forty per cent. of charcoal is obtained, according to the density and state of dryness of the crude fuel. The cost of charring by this furnace is estimated at an average of four shillings per ton of charcoal.

Somewhat differing from the latter in construction, though worked upon the same principle, is the peat-charcoal furnace of East Friesland. It has a solid base sixteen feet long, thirteen wide, and two feet thick; upon this base an oblong furnace is erected, twelve feet long, five wide, and eight and a half high. The end walls of this construction are two feet thick, but the sides are only six inches; parallel with the side walls, and at a distance of eighteen inches, two others are built, each two feet thick, and the end ones are continued at both sides to meet them. By this arrangement a space is enclosed between the interior construction, or the retort, and the exterior wall, and this space serves for the fire channel, in which the products of combustion, from a fire lighted in a hearth, one foot high and eighteen inches wide, with grate and ashpit, made at one end of each of these chambers, circulate for the purpose of heating the retort. An arch or dome completely encloses the inner chamber destined to carbonize the peat; another similar arch is sprung from the outer walls, thus encasing the top of the retort as well as the sides. At the end where the fires are situated, a charging door, five feet high and three wide, is situated, and this, when the process of charring is going on, is kept tightly closed. The floor of the inner retort is hollowed in the middle along the whole length, and the channel thus formed walled by a glazed clay gutter, and covered over with perforated tiles, the whole slightly inclined towards one end. The tar and other fluids which accumulate here during the carbonization, are carried off by a pipe to a tank at a short distance from the retort, and the uncondensable gases conducted back by other pipes to the furnace, where they are burned. For the sake of economy, two or more of such furnaces are built close to each other, by which the time of charring is shortened, less heat being allowed to escape. Such a furnace is capable of producing one ton of charcoal at each operation, at an average expense of four to five shillings.

Another furnace employed in Bohemia is the following:—A circular excavation six feet deep and twenty in diameter, is made, and the base lined with brickwork nine inches deep. Upon this the walls of the furnace are constructed, so that when completed the whole forms a frustrum of a cone. For this end, the walls are five feet thick at the base, and tapering, till, at the height

of sixteen feet, that of the furnace, they are only two, thus leaving a cylindrical space of ten feet in diameter for the charring. At the top or mouth an arch is sprung, and covers the whole in the form of a dome; in the centre of this is left an opening three feet in exterior, and two in interior diameter, and closed by a door, when necessary, with four others at regular distances in the shoulder of the arch. The opening at the base for withdrawing the made charcoal is four and a half feet high, and two and a half wide; this is closed with bricks, and the opening from without secured with boards, so as to keep in the heat as much as possible. A canal is formed round by the base of the wall of the furnace in the interior, nine inches wide and fifteen deep, and two others of the same dimensions intersecting the preceding, one of which opens under the discharging door. Before the charging commences, these channels are filled with brushwood, and partially covered with tiles placed a few inches apart. Before introducing the peat, a pole is fixed in the central opening, and likewise one in each of the others, the lower ends of these filling in the intersections of the circular and cross channels; the charging is then proceeded with, the peat bricks being as nearly as possible placed endwise. When filled, the poles are withdrawn, leaving five vertical flues in their stead. The brushwood in the channel under the dis-

charging door is then ignited, and the fire spreads quickly round the base and across it, so that the heat is equally exerted upon the whole of the peat in this part. All the apertures are left open till a volume of flame freely issues from the orifices in the dome; the charging door is then closed, and further secured by luting or sand being spread over it; the firing flue at the base is likewise secured tightly. The other openings in the dome are only slightly covered, so as to allow the escape of the products of distillation. When the latter cease to be evolved, the openings are entirely covered, and the furnace left to cool for forty-eight hours. In many operations, preference is given to the charcoal manufactured in this furnace, over that prepared in the kilns used at Crouy-sur-l'Oureq.

A few years ago Mr. J. W. ROGERS introduced a furnace for the carbonization of peat, as well as for drying it previous to its being carbonized. Fig. 47 represents a longitudinal section, and Fig. 48 an end view of this ingenious construction. E E is a boarded shed supported on pillars, and open in a great measure at the sides. In the middle of the flooring of this structure a channel is sunk, which constitutes the ash-pit; on each side of this channel a line of rails is laid, forming a railway, on which the carbonizing chambers or kilns, A A A, furnished with small wheels for the

Fig. 47.

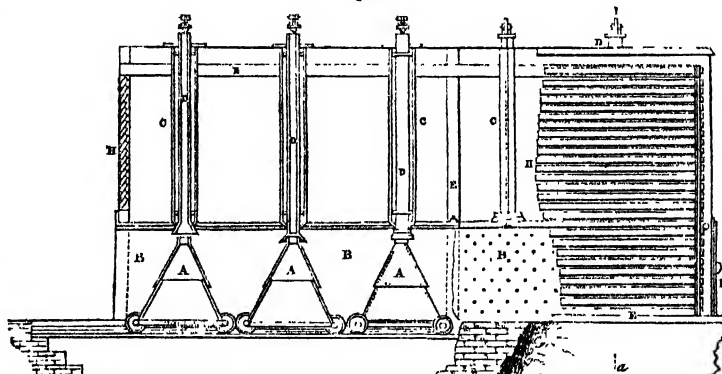
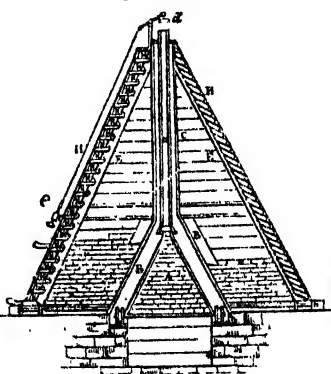


Fig. 48.



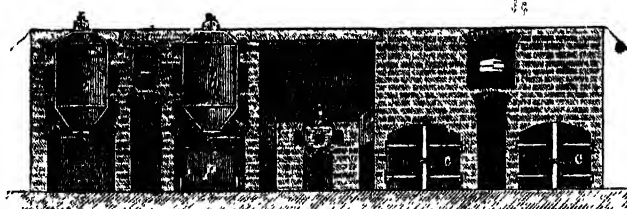
purpose, move. The furnaces are of sheet-iron, upon a framework of the same metal, the whole forming a truncated pyramidal case, of which the base is a grating upon which the peat to be charred rests. These cases are filled by inverting them and introducing the peat, the grate being removed; the latter is then replaced, and after restoring them to their original position, they are rolled along the tramway over the ash-pit. The space through which the ovens pass is encased with sheet-iron, B B, through which, at regular intervals corresponding to the position of the furnaces, pipes, D, D, lead to the top of the building. Within the latter, other movable ones are placed, which fit upon the orifice of the kilns when fixed in the shed; these constitute the chimneys, and they can be raised when it is required to draw out the case from under them. The space between the carbonizers and the roofing of the shed is fitted with shelves for the reception of the air-dried peat, for the purpose of desiccating it more completely. As the exterior covering is formed of a number of movable

louvres, H, H, they may be opened or closed at will. The draught in the chamber of the furnaces is regulated by the flue door, d, worked by the rod, e. When the charring is commenced, some brushwood is introduced into the channel, over which the furnaces are rolled and ignited; the flame lights the peat, and the work proceeds till the contents are carbonized. This is known by no more smoke being given off; the chimneys are then closed by the flue doors, d d, and the furnaces and contents removed. The heat radiated from the sheet-iron plates serves to dry the peat stored on the surrounding shelves. Each of these furnaces carbonizes a charge of about six hundred pounds in five hours, and which yields a result of about twenty-three to twenty-five per cent. of charcoal. Four of these furnaces produce one ton of charcoal in twenty-four hours, and the cost of production, notwithstanding that the raw material would be purchased for two shillings per ton—that is, eight shillings for raw material—has been estimated at twenty-five to thirty shillings; by this the expenses of charring would

equal from seventeen to twenty-two shillings per ton. To prepare the peat, the patentee piles it, after being cut, upon wicker hurdles, one above another, and allows it to remain in this state till dry. The yield of charcoal is stated as from thirty-three to thirty-six per cent.—*Journal of Industrial Progress.*

VIGNOLES has taken out a patent for drying, compressing, and carbonizing peat, the latter being effected by means of steam heated to 450° or 460° Fahr., and the two former by a hydro-extractor, in which the centrifugal force expels the water, and renders the mass denser at the same time. With reference to the charring—the peat dried in the air, or by a current of heated gases forced through a chamber containing it, is thrown into cylindrical vessels, into which steam at a high temperature is forced, till the charring is effected. Fig. 49 shows a vortical section and partial elevation of the apparatus. In this, *a* represents a section of

Fig. 49.



the boiler employed for raising the steam; it is placed over a furnace, the flues of which, after passing under the boiler, branch off and circulate round the carbonizing cylinders, and finally enter the chimney. Two of the charring cylinders are shown at *b b*, of which there are six at each side of the boiler; they are ranged round a coil of piping, *ii*, in which the steam from the boiler is heated to the required degree by a flue, previous to its passing into the cylinders where the peat is charred, by means of pipes connecting them. After the steam traverses one of these carbonizers, it escapes by a pipe, which conducts it over the furnace, to raise its temperature previous to its passage through the next carbonizer in the series. In this way, the steam being first heated is made to traverse a carbonizing vessel and the heating pipe successively, till it passes through the whole of the charring vessels. Ultimately, the waste steam is made to work a low-pressure engine, which turns a fan that forces air, heated by pipes placed in a furnace to 250°, into the drying chamber where the peat is desiccated.

The carbonizers, as may be inferred from the drawing, are conical towards the bottom, and are furnished with a valve or door which is rendered steam-tight, but may be opened when the charring is completed, so as to allow the charcoal to fall into a box, *p*, beneath it, and into which low pressure steam is passed for the purpose of cooling the charcoal. These boxes are constructed of iron, and are well covered, lest the charcoal might spontaneously ignite, to which it is liable, if exposed to air at this temperature; they move on tramways, and can be drawn out when required through the door-ways, *c c*. The top of the cylinder has a similar

opening secured by a screw; through this aperture the charge of peat is introduced.

Several other patents have, within the last few years, been secured by parties for economizing fuel, but to dwell further upon them would be out of place, as many of them come within the range of processes for the manufacture of artificial fuel, more than for preparing the peat alone in an improved state. That of Mr. P. M. CRANE, from its simplicity and its connection with the process already detailed, as pursued by the Irish Peat Company, will be briefly explained. The improvement to be noticed in this patent is the annexing of another furnace to that in which the combustion of the peat was effected in the above-mentioned Company's works. In this appended furnace, the peat is consumed by a blast of air in the ordinary way, and the torrefied gases are conducted by a flue to the second one, which is likewise filled with peat, and the heat thus communicated chars the matter.

In this way charcoal may be prepared without any loss of the products of distillation, as both furnaces may be closed down in the manner described in Fig. 41. The appended hearth or furnace may be modified, so as to enable the manufacturer to burn coal or coke, or even the waste gases formed in the distillation of the peat, turning the caloric and heated products which they yield to the use

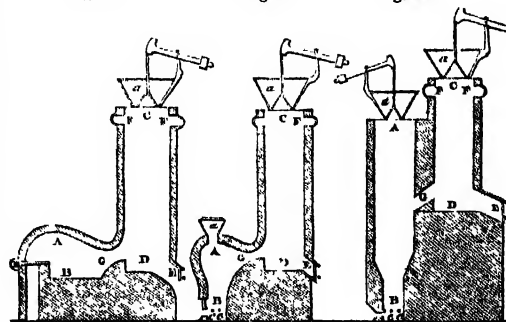
mentioned.

Fig. 52 is a sectional drawing of one of CRANE'S furnaces for preparing charcoal by the combustion of peat alone. In this drawing, *AB* is the furnace connected with another furnace or charring chamber, *CD*, by a flue, *G*. Both these are filled with peat, and closed down in the manner described at Vol. II., page 60. The furnace, *AB*, is lighted, and the blast of air thrown upon the ignited fuel through three tuyeres, *c c c*, at the bottom. The heated gases are forced over into the furnace, *CD*, and passing up through the peat, char it. All the products—as well those from the combustion as from the charring furnace—are carried

Fig. 50.

Fig. 51.

Fig. 52.



off by the exit pipes, *FF*, to the mains and condensers in the usual manner. When the peat in the charring furnace becomes carbonized, the charcoal is drawn out at *E*, into covered tanks, or cast-iron boxes, in which it is allowed to cool out of contact with air. According as the peat becomes consumed in the first, or the

charcoal is withdrawn from the second furnace, the space rendered vacant is filled by charging the hoppers, *a a'*, and letting this charge into the furnaces in the usual way. Figs. 50 and 51 show the construction of the furnaces intended to consume coal, or anthracite, and gas, for the purpose of generating heated products for distilling peat. Fig. 51, for coal, needs no explanation, as its operations are similar to the foregoing. When gas is employed, it is conducted to the hearth, *A B*, by the flue, *I*, Fig. 50, and, being ignited, a blast of air is introduced by pipes communicating with a blast-pipe, *H*. The pressure of this blast forces the heated products through the carbonizer, *C D*, producing the intended results.

Such are the methods in common use where the preparation of peat-charcoal has been industriously pursued, and some of them offer considerable advantages. Of the analyses of peat-charcoal little need be said here, as the analyses of peat already given will throw some light upon this part of the subject. As a generator of heat, good peat-charcoal is as efficient as bituminous coal; and some varieties are even above the average heating-power of the latter kinds of fuel.

COAL.—This is by far the most valuable and extensively disseminated fuel, or source of heat, and is defined by REDFERN—*a compressed and chemically altered vegetal matter, associated with more or less earthy substances, and capable of being used as fuel.* This definition expresses all that is necessary; but its truth can only be established by the concurrence and aid of several branches of knowledge. For instance, animal matters may, by a process of decomposition, yield a mass of carbonaceous substances, which could not be distinguished from similar vegetal ones by the naked eye. In such cases, the microscope and chemical analysis lead to a certainty as to the nature of the originals; the former by revealing the texture of the fibrous matter of the plant, and the latter by the separation and estimation of those bodies into which it has been partly resolved. Before giving any detailed account of the process by which coal has been produced, it may be well to explain briefly the proofs which are cited in argument to show what coal is; and for much of what follows on this point, the Editor must acknowledge himself indebted to the treatise on *Fuel and its Applications*, by RICHARDSON and RONALDS.

Evidences of the origin and character of coal may be gathered from the geological position of the deposit, the mineral characteristics, the chemical nature, and the visual appearance of the substance under high magnifying power. It is the opinion of geologists that coal may be viewed as a stratified rock, in which layers of other geological formations—such as clays, sandstones, and limestones—are found. These, in themselves, form vast deposits, or strata; but, in this respect, there is no difference between them and the coal-beds, excepting in the nature of the substances. How the matter has become so stratified, is a question to be afterwards considered. The coal seams vary from a mere film, or a layer of less than a quarter of an inch in thickness, to three or four feet. It is not often, however, that the deposits are of the latter dimension. In mines, where the depth of the carbo-

naceous deposit averages from ten to twenty or thirty feet, soams of mineral matters interpose themselves at intervals, varying as to the distance between them, but rarely exceeding the limits above assigned. All coal-beds contain these foreign strata, or *partings*, to a greater or less extent; they seem to have been the result of the precipitation of matters held mechanically suspended in water. The thickness of these intervening deposits is found to vary considerably from a mere seam to a bed of several feet. In many cases the mineral matter, thus interstratified, has become so saturated with bodies emanating from the coal, or during its formation blending with the carbon, that it ignites and burns like coal, only that its bulk of earthy substances remains, often retaining the original form. Such matters are frequently observed in the burning of many varieties of coal, and in common language are called *slates*, *butts*, or *basses*. This blending of the two substances is often so unmistakable, that at a glance it may be ascertained whether the *shale*, as it is called, is argillaceous or calcareous; but when it is known that the coal-beds belong to the alluvial deposits, it will be evident that the intermixture of mineral and organic matters must have proceeded collaterally, even although the latter appears in such excess as completely to obliterate any traces of the former. In Great Britain, coal is principally in the carboniferous formations, occupying a posterior place in the series of stratified rocks; and where the same stratification of limestone rocks is met with in other countries, beds of coal are generally to be encountered. Still coal is not confined to this set of rocks; it is found in different parts of the strata, from the Devonian down to the most recent tertiary formations.

Mineralogical Characters.—Although here the subject under consideration is spoken of as a mineral, it ought to be remembered that, strictly speaking, it is not a pure one, but a mixture of various matters, of which carbon is the principal. It may, however, be regarded as organic matter *mineralized*; and, as it manifests some of the general properties of minerals, these will be noticed. The several known varieties of coal possess each some distinctive feature, differing from one another in hardness, fracture, *et cetera*. Several species break up into cubical and rhomboidal fragments; whilst others—such as the anthracite—are nearly devoid of crystalline structure. Generally, the fracture is conchoidal, uneven, fibrous, or slaty; in Boghead coal the fracture is conchoidal, perpendicular to the plane of stratification, but slaty when parallel. In color, it presents according to the variety every difference of hue, from jet-black to brownish-yellow; many kinds have a glossy brilliancy; others—such as the varieties of anthracites—a beautiful semi-metallic iridescent lustre; whilst some—such as the Wemyss, Methil, and other varieties of cannels—have a dull appearance. Coal exhibits great differences in point of hardness, although none of the varieties possesses it in an eminent degree. Anthracite has a specific hardness of two to two and a half. The gravity of several kinds of coal differs according to the texture and age; the lightest kinds have a density bordering on 1.00, whilst the heaviest range from 1.75 to 2.00.

Chemical Characteristics.—From what has been stated, it is evident that a chemical examination of coal would, in the simplest manner, lead to its division into inorganic and organic substances, and that these are contained in it in variable proportions: and, further, that each of these classes can be resolved into other substances, the most characteristic of coal being those generated by the vegetal portion. This arises from the large proportion of the elements always found in it—namely, carbon, hydrogen, and oxygen; and which, by the action of heat out of contact with air, are converted into numerous and peculiar substances.

Distillation in close vessels resolves coal into solids, liquids, and gaseous bodies, consisting of carbon or coke, tar, ammoniacal liquor, benzol, naphtha, naphthalin, paraffin, paraffin oil, and illuminating and other gases, in various quantities. By the detection of these, and the proportion in which some are contained in the substance, a good inference may be drawn as to whether the body be coal or otherwise: nevertheless, the evidence is not so conclusive as when the investigation is conducted microscopically.

Microscopic Characters.—By the use of the microscope, the most conclusive proof of the origin of the coal is attained. Dr. AITKEN of Glasgow has carefully investigated the structure of coal, and found that, even in the most altered specimens, traces remain sufficiently characteristic to prove that the material is of vegetal origin.

In the variety of bitumens, whether pure mineral tar, or asphaltum, no such structure is observable, and consequently, in the hands of a chemico-microscopist there is nothing to render the detection of real coal a matter of uncertainty.

Origin of Coal.—Such being the principal or more marked characters by which a substance submitted to examination may be affirmed to be coal, it will now be desirable to enter more fully upon the origin and nature of this product, in reference to its value as a fuel. Allusion has already been made to the analogy which exists between peat and coal, and the reader will have inferred that coal, like peat, has been produced by the decomposition of species of organic growth. All who have given attention to the composition of coal, and the geological position it occupies, concur in this view of the subject; and the Editor will now explain briefly the different opinions advanced as to the manner in which the change and disintegration of the vegetal products have been produced.

It may be said that the process which has operated to convert countless reproductions of plants into peat bogs, has been similar in the case of coals to some extent; but, geologically considered, it is evident that the oldest peat deposits are of modern formation, when compared to the most recent beds of coal. Of the vegetal origin of the latter, no doubt can be entertained, even if the microscope had not revealed the fact in the more compact varieties, since among other indications, even the trees have been found in their natural position converted into coal. The character, the variety, and the immense mass of vegetal matter thus converted, have led to the conclusion that the several species of plants whence coal has resulted were indigenous to a

southern or equatorial climate, as it is certain they could not flourish so luxuriantly in the existing temperature of northern latitudes. The varieties most commonly distinguished in the different strata are ferns, calamites, sigillariæ, stigmariæ, and others; in fact, no less than three hundred distinct kinds have been detected.

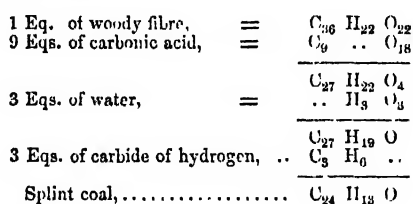
As to the manner, however, in which the strata of the coal deposits have been formed, there is much difference of opinion. Some geologists suppose that they were originally peat, the several successive layers being occasioned by successive subsidences of the land; whilst others assert that the various constituents were originally conveyed by currents to estuaries and deltas, where, being buried under the sand, mud, and debris brought down by the current, they were subsequently submitted to agencies which effected their carbonization. It is certain that the surface of the globe was at one time nearly submerged in an ocean, in which state it remained till, by the effects of volcanic eruptions, portions were uplifted, causing a corresponding depression in other places, and thus forming valleys, the forests and vegetation of which were buried under layers of loose earth and mud. At the same time, it would require many such forests to constitute a layer of the thickness of some of the coal seams, and these can scarcely be imagined to have been produced otherwise than by the drifting of vast accumulations of trees and plants into the basins in which coal is now found.

But leaving geologists to discuss and settle these questions, it is more in accordance with the plan of this work to attend to the chemical changes which have contributed to the conversion of the organic fibre into the carbonaceous matter in question. Whether the organic products on the surface of the earth were collected by changes in the relative position of the earth's solid crust, or by the force of violent currents, such as the large American rivers of the present day, it may be admitted and assumed as a fact that they were embedded with other matters saturated with moisture. The first natural change under such circumstances would be a fermentation of the albuminous matter and the gum, by which their molecular constitution would be broken up, and bodies of a simpler composition formed. The exclusion of the air after a short time would suppress the eremacausis or decay of the substance of the wood and fibrous matter, but the equilibrium of the affinities of the elements in the plants being broken, and considerable pressure being exerted, coupled with a certain rise of temperature, the change of elements arising from the new elective affinities would contribute to remove the hydrogen and oxygen to that extent which is observed in the composition of coal. The oxygen and hydrogen being most subject to the effect of this metamorphosis, these elements, leaving the carbon, would more readily assume their simplest and most permanent state of combination; but, as in the process of destructive distillation already alluded to, the conditions supplied are capable of inducing the water thus constituted to react upon a portion of the carbon, so in the coal formations, where the enormous pressure must have operated with an effect

in some degree equivalent to an increased temperature, the moisture and excess of hydrogen would convert the remaining substance into carbonic acid and carbides of hydrogen respectively. The actual facts, as determined in coal mines, seem to bear out this view.

From such considerations it will be readily concluded that the elementary composition of coals must be different from ligneous fibre; but following up the assumed alteration by a symbolical representation, the composition of coal offers very conclusive grounds to warrant the opinion that the former has resulted from the latter in the manner indicated. For instance, the composition of woody fibre may, as already stated, be represented by the equation $C_{36} H_{22} O_{22}$; and if, by the change above indicated, three equivalents of carbonic acid be extracted, represented by $C_3 O_3$, there results $C_{33} H_{22} O_{19}$; and if from this one equivalent of hydrogen be taken away, represented by H, there is left a formula— $C_{33} H_{21} O_{19}$ —corresponding with the composition of a variety of coal worked in Laubach.

In like manner the formula of splint coal may be deduced from the elements representing woody fibre, by supposing that the combined agency of heat and pressure removed nine equivalents of carbonic acid, three equivalents of water, and three of carbide of hydrogen, thus:—



According to the degree of force exerted upon the decomposing substance, and the period of time in which this change was taking place, it is evident that the substances would be more or less removed from one another in composition. In the first example stated above, the formation bears every indication of recent production, when compared with the second; and this accounts for the close analogy between the two formulæ of wood and that species of coal. In other kinds, such as many of the anthracites, the alteration is much greater than even in the splint already referred to, and it is much more difficult to recognize the analogy between them and wood, for often all the oxygen and hydrogen are removed, so that nothing is left but carbon and the mineral matters intermixed with it.

Coal Measures.—The region of the coal formations is very extensive, and includes many strata, all of which are known as the *coal-measures*, or carboniferous group. Properly speaking the first of these is what is termed the *under-lay*; this is, a tough argillaceous substance, which, upon drying, turns grey and becomes friable. It retains considerable traces of carbonaceous matters. Two other strata beneath this are, however, included in the group; these are the mountain limestone, which varies very much in thickness, being sometimes nine hundred feet, and the old red sandstone upon which it rests; the latter stratum ranges from two hundred to two thousand feet in thickness. Next to the underlay in the ascending scale comes the seam of coal, or modified organic matter, varying from less than a quarter of an inch to several feet. Above these the upper layer or roof, as it is termed, rests. It is composed of slaty clay abounding in vegetal remains, as well as with crustaceæ, and several other matters. Interstratified with the latter are found various other substances, which seem to have been accumulations drifted by currents, such as laminated clay, grit, limestone, granite, sandstone, and other rocks.

All these deposits at one time, doubtless, formed regular horizontal layers, but through the effects of expansion in the depths of the earth, they have been distorted and thrown into undulated positions, and where the internal force has been very great, they have, by the upheaval of the subordinate strata, been formed into large valleys or basins. From the position of these layers, previous to such convulsions occurring, it is obvious that as the older deposits of mountain limestone, old red sandstone, *et cetera*, emerged in succession, so the more modern layers, including the carboniferous, would appear at the surface. This appearance is termed the cropping out of the strata, and serves to indicate the side of the basin. Considerable irregularity is occasioned by further subterranean disturbances which tend to alter the position of the strata subsequently to the first upheaval of the older formations. These generally render the deposits somewhat irregular in shape, so that they seldom form a true basin. In some localities, as in the Leicester and Warwickshire coal-field, none of the characters of a basin are observed; in the latter instance, the seams are surrounded on all sides by overlying deposits, under which they dip or incline to a considerable depth, and extend to an area unknown.

Fig. 53 represents this field in section, showing the alluvial deposits at A A; the new red sandstone, or marls,



at BB; the carboniferous shale and coal at CC, interlaid with carboniferous grit, or sandstones, DD; E, beds of magnesian; and F the stratum of mountain limestone, resting on the old red sandstone, G. Fig. 54 gives a

faint idea of the disturbances which are occasioned in the various beds by fissures filled with other materials. These veins are, in the language of the miner, called *dykes*, as they are the means of separating the strata

into compartments, which are designated *fields*. Besides this term, another is applied significant of the displace-

ment of the bands of coal from their original position—namely, *shifts*. Where these occur, the seam is

Fig. 54.



thrown out of its level, and, according as it is removed to a higher or lower one, the fault is called an *up-throw* or a *down-throw*. The displacement occurring at many of these shifts is considerable, and gives no small trouble to the miners. The largest known is that which runs through the Northumberland and Durham coal-field, and is termed the Ninety-fathom dyke, from the fact that the seams of coal are ninety fathoms lower at one side of the slip than at the other. Various matters fill these intersecting veins; hard and soft sandstone is contained in the one in question, which in some parts, especially at the Montague Colliery, attains a width of twenty-two yards. Two other dykes spring from this at the Southern side; one of which takes a South-eastern direction, and is about twenty yards in breadth; the other a South-western one, and attains a breadth of seventy yards. Both branches are filled with the same material as the primary one, but do not appear to have caused so great a disturbance at their point of intersection. These are represented in the foregoing drawing at F F, S S; but the others, although they partake of the nature of a dyke, are not recognised as such. For instance, those shown at D D' are of a different character, and are called *whin-dykes*, containing products of igneous origin, such as basalt, tondstone, *et cetera*; these do not always cause a removal of the strata from the ordinary level. Evidence of their eruption in a state of fusion exists in the fact, that the coal in their vicinity is more or less charred and converted into a true coke; besides, many substances of a fusible nature are acted upon, and indicate the powerful temperature which has pervaded the place, and which is often productive of great loss by consuming or changing the coal into anthracite, as shown at D' in the figure, where the basalt and other products accumulate. The *hitch* is another of those dykes, and is so called when its thickness is less than that of the

seams of coal which it intersects: this is represented at H H in the drawing. Smaller veins of foreign matters lying in any direction contrary to that of the strata are designated *faults* or *troubles*, from the annoyance the miners experience by the interruption of their work. Several of these are seen at T T; and although in working they cause much trouble, yet sometimes they contribute to render a field more valuable, since, by the depression which they occasion, seams of coal are brought in which might otherwise be lost. An example of this is given in the drawing referred to, where, by the down-throw of the strata between F F and T T, two seams of coal are brought in which would not otherwise be contained in it. Other interruptions or irregularities in the coal seams are designated *bands* and *nips*; the former, shown at B, are thin deposits or beds of grit or shale occurring in the middle of a seam of coal, and which, from being very thin, gradually acquire greater thickness, till ultimately they reduce the seam so much as to render it valueless; the second, shown at N, is a sudden local thinning of the seam, from an excrescence of the roof or floor.

The distribution of coal is very extensive; it is found in almost every country, although to a very unequal extent. The United States may be considered as the most highly favored in this respect, if the area of their coal deposits be taken into account, irrespective of the extent to which they are worked. It happens, however, that, from the abundance of wood, the home consumption of the article is limited, while the conveyance is costly, so that the benefits which result from valuable coal seams in other nations, remain to be developed in America. According to the statistical calculations of MITCHELL, the annexed table represents the amount and varieties of the mineral coal treasures in the United States:—

TABLE SHOWING THE AREA OF COAL IN THE UNITED STATES OF AMERICA.

	Area of the State Square Miles.	Coal Areas Square Miles.	Proportion of Coal.	Species.
1. Alabama,	50,875	3,400	1-14th	Bituminous coal.
2. Georgia,	58,200	150	1-386th	"
3. Tennessee,	44,720	4,300	1-10th	"
4. Kentucky,	39,015	13,500	1-3rd	"
5. Virginia,	64,000	21,195	1-3rd	"
6. Maryland,	10,829	550	1-20th	"
7. Ohio,	38,850	11,900	1-3rd	"
8. Indiana,	34,800	7,700	1-5th	"
9. Illinois,	59,130	44,000	3-4ths	"
10. Pennsylvania,	43,960	15,437	1-3rd	{ Bituminous and Anthracite.
11. Michigan,	60,520	5,000	1-12th	
12. Missouri,	60,384	6,000	1-10th	
	565,283	133,132	.... nearly 1-4th the area of the twelve States.	

It is certain that this vast tract of carboniferous deposit is not in its whole extent calculated to yield workable coal; still, making every allowance for those parts which, from their thinness or depth, cannot be profitably worked, it is evident that the area is sufficient to insure, for an almost indefinite period, a superabundant supply. Although within the last thirty years the coal trade of the United States has increased from an annual produce of three hundred and sixty-

five tons to five millions of tons, yet it must be evident at a glance that this enormous source of wealth is permitted to lie comparatively dormant at the present day. In British America the coal measures are not so extensive as in the States; it is doubtful, indeed, whether any workable seams exist in Canada, but fields of considerable area are known in New Brunswick and Nova Scotia, making about two-ninths of the whole area; and Newfoundland is said to be rich in this mineral.

TABLE OF THE PRINCIPAL COAL FIELDS IN THE BRITISH ISLES.

	Estimated workable area in acres	Number of workable seams.	Estimated total thickness of workable coal in feet.	Thickest bed in feet.	Thickness of coal-bearing measures.
1. NORTHUMBERLAND AND DURHAM DISTRICT:—					
Newcastle coal field,.....	500,000	18	80	7	..
2. CUMBERLAND AND WESTMORELAND, AND WEST RIDING OF YORKSHIRE:—					
Whitchaven and Akerton,.....	80,000	7	..	8	2,000
Appleby—three basins,.....	17,000	..	..	..	..
Sebergham—Cumberland,.....	?	1	3	3	..
Kirkby-Lonsdale,.....	2,500	4	17	9	..
3. LANCASHIRE, FLINTSHIRE, AND NORTH STAFFORDSHIRE:—					
Lancashire coal field,.....	380,000	75	150	10	6,000
Flintshire,.....	120,000	5	39	9	200
Pottery—North Staffordshire,.....	40,000	24	38	10	..
Cheadle, do.,.....	10,000	..	..	..	..
4. YORKSHIRE, NOTTINGHAMSHIRE, AND DERBYSHIRE:—					
Great Yorkshire coal field,.....	650,000	12	32	10	..
Darley Moor, Derbyshire,.....	1,500	..	..	..	..
Shirley Moor, do.,.....	..	..	..	..	..
5. SHROPSHIRE AND WORCESTERSHIRE:—					
Coalbrook Dale, Shropshire,.....	21,000	17	40	..	..
Shrewsbury, do.,.....	16,000	3	..	..	..
Brown Clee-hill, do.,.....	1,300	3	..	..	..
Tillerstone Clee-hill, do.,.....	5,000	..	..	..	..
Leekey-hill, Worcestershire,.....	650	?	..	..	..
Bewdley, do.,.....	45,000	?	..	..	..
6. SOUTH STAFFORDSHIRE:—					
Dudley and Wolverhampton,.....	65,000	11	67	40	1,000
7. WARWICKSHIRE AND LEICESTERSHIRE:—					
Nuneaton,.....	40,000	9	30	15	..
Ashby-de-la Zouch,.....	40,000	5	33	21	..
8. SOMERSETSHIRE AND GLOUCESTERSHIRE:—					
Bristol,.....	130,000	50	80	..	..
Forest of Dean,.....	36,000	17	37	..	..
Newent, Gloucestershire,.....	1,500	4	15	7	..
9. SOUTH WELSH COAL FIELD,.....	600,000	30	100	9	12,000
10. SCOTTISH COAL FIELDS:—					
Clyde Valley,.....	1,000,000	84	200?	13	6,000
Lanarkshire,.....					
South of Scotland—several areas,.....					
Mid-Lothian,.....					
East-Lothian,.....	?	24	94	..	4,400
Kilmarnock,.....	?	60	180	13	6,000
Ayrshire,.....	?	3	40	30	..
Fifehire,.....	?	?	?	21	..
Dumfries coal region,.....	45,000	10	55	6	..
11. IRISH COAL FIELDS:—					
Ulster,.....	500,000	9	40?	6	..
Connaught,.....	200,000	..	..	..	..
Leinster—Kilkenny,.....	150,000	8	23	..	..
Munster—several,.....	1,000,000	..	..	..	..

In the area of her coal deposits, Britain ranks next to the United States, and greatly exceeds the latter in the extent and value of her workable mines. The total extent of coal in England is estimated at about six thousand and thirty-nine square miles, or one-eighth of the whole area; in Scotland, one thousand seven hundred and twenty square miles, or one-eighteenth of the whole; and in Wales, one thousand one hundred and sixty square miles, or about one-sixth of its entire extent.

The principal deposit is that known as the great central coal-field, lying in South Yorkshire, Nottingham, and Derby; it is no less than sixty-five miles in length, and averages in some parts a breadth of twenty-five, making on the whole an area of about six hundred and fifty thousand acres. Next to this may be classed the Lancashire and Cheshire field, including the Wigan district; this deposit is about fifty miles in length, with an average breadth of ten miles, and is, therefore, no less than four

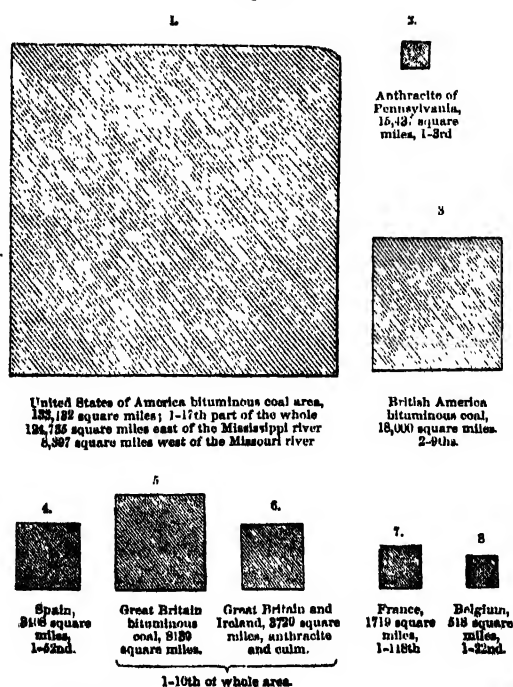
hundred thousand acres in area. Another field, which seems an extension of the latter, runs from its south-eastern extremity through Cheshire into Staffordshire, in which are the Cheadle, Macclesfield, and Pottery coal-fields. The third great deposit is that of Durham and Northumberland, which stands probably first in the list as to the quantity of fuel that is obtained from it. This vast deposit—called also the Newcastle coal-field—is estimated at thirty-six thousand acres situated in Durham, and about one hundred and fifty thousand acres in Northumberland. Of this extent about sixty-seven thousand acres are already worked. Estimating the content of this field at a thickness of twelve feet, each acre of four thousand eight hundred and forty square yards is supposed to yield a ton of coal per cubic yard, thus making the total weight of coals in this field about ten million tons, including the quantity destroyed and rendered unserviceable.

Besides the above, there are several other mines of secondary importance, from which a considerable quantity of coal is annually extracted. These, with their area, thickness, the number of workable seams, *et cetera*, are exhibited in the table in previous page, which is extended to embrace Great Britain and Ireland.

On the Continent the chief coal-producing countries are Spain, France, Belgium, and Prussia, although several others possess many valuable coal basins which hitherto have been little worked. The following diagram—Fig. 55—taken from TAYLOR's work gives a moderately comprehensive view of the comparative area of coal in the various countries that have been mentioned. It includes not only the workable seams, but the entire carboniferous area:—

DIAGRAM OF THE SUPERFICIAL COAL AREAS OF VARIOUS COUNTRIES.

Fig. 55.

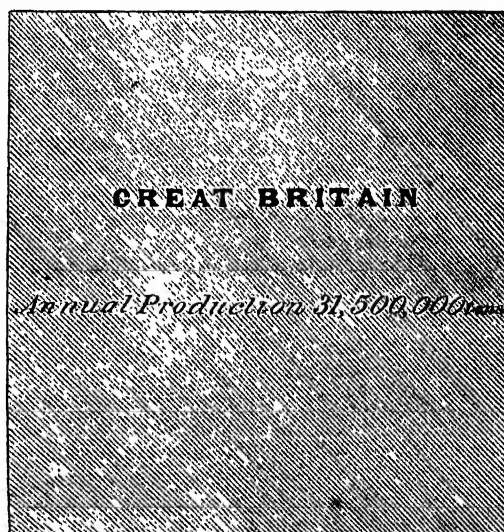


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It is evident, however, that this diagram, with its numbers, does not exhibit the relative value of the coal-fields in the different countries. This must depend on many circumstances, apart from the mere consideration of superficial extent; but their productiveness at the present day is shown in the next diagram—Fig. 56.

DIAGRAM OF THE RELATIVE AMOUNTS OF PRODUCTION OF MINERAL COMBUSTIBLES IN THE SIX PRINCIPAL COAL-PRODUCING COUNTRIES OF THE WORLD, IN THE YEAR 1845.

Fig. 56.



A summary of the whole, exhibiting at one view the extent of coal area, the quantity raised in 1845, with its relative proportion to the area, and, finally, the official estimated value of the places of production, is added in the annexed table:—

K

Countries	Surface million of coal formation.	Tons of fuel raised in 1860.	Relative parts of 1000.	Official estimated value of the piece of production.
Great Britain, . . .	11,859	31,500,000	642	9,450,000
Belgium,	518	4,960,077	101	1,680,000
United States, . . .	133,132	4,400,000	89	1,373,000
France,	1,719	4,141,617	84	1,603,106
Prussian States, . .	not	3,500,000	70	856,370
Austrian States, . .	defined.	659,340	14	165,290
Total,		49,161,034	1000	15,108,729

It may be added, as the result of recent researches, that Asia and even Africa have been found to be very well stocked with fossil fuel; and, indeed, there can be little doubt that the East Indies and China will yet become coal-producing countries. The same may be said of Australia, and other British colonies.

DIFFERENT KINDS OF COAL.—From the acknowledged transformation which the substance of the coal has undergone, and from its progressive nature, it is natural to expect that the material so produced should have very different properties, according to its more or less advanced state of decomposition. Such is really the case, and various species of coal exist differing by slight and regular gradations from the most recent lignite or brown coal, in which the outline of the wood may be easily traced, up to the most perfect anthracite, in which every vestige of the original is lost, and nothing remains but a conglomerated charcoal. Many of them, indeed, have so close a resemblance to one another, and pass so imperceptibly from one stage to the other, that it is almost impossible to mark the distinction between them. Several species, however, may be classified on broader data, grounded partly upon age, partly on their physical appearance, and partly on their composition. It is by these criteria that the classification of the fossil into brown and black coal, or into the bituminous and non-bituminous varieties, is effected. Several members are contained in each of these groups, but many kinds blend with each other in such a manner that it is difficult to draw a line of demarcation between them. Classifying the chief varieties according to their supposed age, the whole of the coal measures may be included under three heads; namely, the younger coal of the *tertiary* deposits, the older bituminous kind of the secondary formations, and the anthracites of the older transition series of rocks.

Lignite.—The coal of the tertiary formation, which includes several varieties, has been designated *brown coal* or *lignite*, from its characteristic appearance. This species, termed also bituminous wood, is the most interesting, as clearly exhibiting the ligneous structure of the matter from which it derives its name, in such perfection as to furnish sufficient data for instituting a diagnosis of the plants of very remote eras. It has a brown color; but this varies with the depth of the bed. The Bovey coal of Devonshire is a member of this class; it presents a distinct woody structure, and very rarely a conchoidal fracture; it is devoid of lustre, is brittle, and burns readily, leaving a white ash. Some others, however, such as the more compact kinds, exhibit a more or less conchoidal fracture and slightly resinous lustre. In the latter case, the color is brownish-black; it has some

called earthy-brown coal, to distinguish it from another kind of the same species, designated *pitch-coal*, the structure of which is more dense, as shown by its distinct conchoidal appearance when broken. Between these extremes may be found the *brown earthy coal*, so named from its argillaceous fracture, crumbling into loose friable particles; and *moor coal*, in which the structure of the plants is obliterated, and which exhibits in its fracture more or less lustre.

The species of coal embracing these varieties is encountered in several of the formations on the Continent; at Bovey Tracey in Devonshire, near Lancaster, and at Lough Neagh in Ireland, where it constitutes three beds, averaging in some parts a thickness of sixty feet. It is very inferior as a fuel to the other varieties of coal which will be presently described. As dug from the mine it is more or less impregnated with moisture, which it persistently retains, and which, even if entirely expelled, is reabsorbed with great avidity. Thus REINSCH determined in a sample of wood coal from the Upper Pfalz, in Bavaria, forty-three per cent. of moisture, and in an earthy-brown coal, thirty. VARENTRAPP found no less than forty-eight per cent. of moisture in fresh lignite from Helmstadt, and further ascertained that, after thorough desiccation and re-exposure to air, about eight per cent. of water was again absorbed. By stacking this coal for some time, much of the water evaporates, so that the moisture averages about thirty per cent.; but if the exposure be made in summer, the quantity is lessened to twenty per cent., the bulk of the coal undergoing a corresponding reduction.

Distinct from the foregoing in physical appearance, though to some degree analogous in chemical composition, are those non-compact bodies, termed bituminous coal, in which the structure of the plants is entirely effaced, and the color and appearance are indicative of a pretty advanced stage of decomposition. Of this kind there are several varieties, distinguished by characteristic properties. When treated with other they all yield more or less bitumen, and hence the general designation, *bituminous*, to distinguish them from the anthracites proper, which afford none of that substance. The following most marked varieties of this description are *caking coal*, *splint coal*, *cherry coal*, and *cannel* or *parrot coal*.

Caking coal is a moderately compact fuel; its fracture is uneven, and its lustre varies from a resinous to a velvety or greyish-black appearance. When heated, it breaks into small pieces, if the amount of bitumen be not more than the average, but afterwards the fragments agglomerate, and form a hard compact body; when the per centage of bitumen is high, it fuses at once into a pasty mass, and during the application of the heat bubbles of gaseous matter escape, leaving ultimately a carbonaceous substance, in which all traces of the original are effaced. Ignited in air, it burns with a yellowish flame, which is intermittent, unless the fuel be kept repeatedly stirred, so as to prevent its caking. The latter tendency renders this coal unsuitable for many operations where great heat is required, as the draught is impeded by its caking properties. It is, however, a valuable fuel, especially

as it is very often possessed of qualities which render it applicable for the manufacture of gas and coke, the latter being most eligible as a heating agent where the coal itself cannot be employed.

Caking coal is very general, being met with in almost all the coal-fields of Great Britain, but more especially in the Newcastle and Wigan districts.

Splint or Hard Coal.—This variety occurs most abundantly in the Glasgow coal deposits, where, for general application, it is highly prized. Its color is black or brownish-black, and its lustre resinous and glistening. When broken, the principal fracture appears imperfect and slaty, but the transverse one shows it to be fine-grained, uneven, and splintery; hence, as well as from its hardness, the term splint. It kindles with greater difficulty than the preceding variety, but when once ignition has taken place, it produces a fine clear fire, and throws out much heat.

Cherry or Soft Coal.—The similarity in physical appearance between this and the caking coal is very great, though for the most part the lustre of cherry coal is much more splendid, and hence the name given it by the miners. It differs from caking coal in not undergoing fusion when heated. Owing to its great brittleness, it is not economical in the working. It readily ignites, and makes a lively fire, yielding a clear yellow flame, but is consumed rapidly. This species is likewise met with in the upper strata of the Glasgow beds, as also in Staffordshire, in the Lancashire district, *et cetera*.

Cannel, Candle, or Parrot Coal.—This variety has a very compact and even texture; a shining resinous lustre, and a color varying between a jet and a greyish or brownish black. The lustre of cannel coal is sometimes not so very distinct as that of *pitch coal*, which is a species of the caking kind; its compact texture and gravity are sufficiently characteristic to distinguish it from the other sorts. The fracture of cannel is flat, conchoidal in every direction, and sometimes slaty. It takes a good polish, and on this account is manufactured into numerous articles, such as inkstands, snuff-boxes, beads, *et cetera*.

Cannel is found in several coal basins, but most abundantly in the Wigan district, at Lesmahagow, near Glasgow, and at Coventry. It is so named from its property of burning and yielding a bright flame like a candle. The other name, *parrot coal*, which is of Scottish origin, is derived from its decrepitation when thrown on the fire, owing to pieces of the coal flying off when heated.

Many other local appellations are given to the coal even from the same field, if it includes many seams, but these are of little interest to the consumer.

Anthracite.—In speaking of the origin of coal, allusion has been made to this variety as being the oldest, and, consequently, the furthest removed from its vegetal source in composition and physical characters. This fossil, which is sometimes known as *glance* or *stone coal*, is a hard compact substance possessing much lustre, often iridescent; the more perfect variety is entirely free from bituminous matter, and hence it constitutes a class of the coal formation in itself. These characters are not observed in all the anthracites, which

generally retain more or less bituminous coal interstratified or otherwise mixed with portions reduced to the state of true anthracite. The mixed varieties, or semi-anthracites, admit of being employed as a substitute for caking coals in many cases where a true anthracite would not answer the purpose.

This is the densest of all the coals known, excepting such as are very earthy or otherwise mineralized. It contains, when a true anthracite, only carbon, water, and inorganic salts, but generally more or less hydrogen and oxygen, besides the proportion of the latter elements in the form of water. Anthracite is ignited with great difficulty, and being dense, and having a tendency to break up into fragments when heated, in consequence of the expulsion of the water contained in it, it is not calculated to produce a strong fire in the ordinary grate or furnace, although, when once thoroughly ignited, its calorific power is very great. By a suitable modification of the grate or furnace, and proper management, it may in numerous instances—not the least of which is its application to smelting—be employed with advantage.

Anthracite is found most extensively in America, where it constitutes immense deposits. In England, it is chiefly worked in the South Wales coal-field, although it may be met with in large quantities in other basins. The total area of this description of fuel in Great Britain and Ireland is about three thousand seven hundred and twenty acres.

CHEMICAL COMPOSITION OF COAL.—The localities and general characteristics of the principal varieties of coal having been noticed, the Editor will proceed to a more minute examination of its composition. It has been already laid down as a general principle, that the value of a fuel is proportional to the amount of carbon which it contains. Like other rules, however, this admits of exceptions, and, for some purposes, the coal is valued according to its per centage of hydrogen. This is especially the case with coal intended for gas manufacture, and also when employed as a fuel in such arts as require the heat to exert its power at some distance from the fire. Moreover, other ingredients may be contained in the coal in proportions very insignificant when compared with the carbon and other inflammable portion, but still so injurious in their effects as to render the fuel unadapted for many purposes to which it might otherwise be applied with good results. Among these are found sulphur, arsenical and other kinds of pyrites; and similar prejudicial effects are produced by the presence of considerable portions of sulphates, or, in fact, of any mineral matters which undergo no change during the combustion. The pyritous ingredients are, however, the most deleterious, as during combustion they evolve sulphurous acid, and if arsenic be contained in the coal—which is fortunately a rare occurrence—arsenious acid will be eliminated. Now, both the sulphurous and arsenious acids are highly obnoxious and dangerous, and ought to be avoided as much as possible. From all these considerations, it is evident that, to determine the quality of any species of coal, with a view to ascertain its fitness for a given purpose, nothing short of a knowledge of its ultimate composition can be relied on; and

this can only be arrived at by careful analyses. Before proceeding further, therefore, the differences in chemical composition of the principal varieties will be examined.

Lignites.—It has been stated that this species of coal belongs to the tertiary or latest formations, and retains much of the ligneous structure from which it derives its name. The general results of its distillation are a coke or charcoal containing mineral matters—aqueous products, more or less charged with pyroligneous acid and ammonia, tar, carbides of hydrogen, carbonic oxide, and carbonic acid. The relative proportions of these vary in different specimens; but, on the whole, they exhibit a great similarity of composition in this substance, as compared with peat and wood—more especially the former. By further treatment the analogy is more fully established: thus, when lignite is

treated with caustic potassa, it dissolves, yielding a dark-brown liquor, which affords a substance resembling in its reactions ulmin, the principal ingredient of peat. Again, the coke which remains after the distillation of lignite retains the outline of the sample operated upon, just as in the case of peat or wood, a circumstance which happens with no other kind of coal. It is to be observed, however, that these characteristics apply only to strongly-marked lignite or brown coal. The transition from this to true coal is gradual, both as regards the physical and chemical properties. The composition of lignite varies according to the age and position of the deposit, but this difference is chiefly confined to the mineral and aqueous constituents.

The following table, from RICHARDSON and RONALDS, exhibits the inorganic constituents of various lignites and brown coal:—

Variety of Brown Coal or Lignite		Ash.	Observer.
Bohemian,.....	Lignite from Aussig,.....	5.35	Balling.
	" " Hegendorf, ..	5.51	
	" " Neuendorf, ..	6.93	
	" " Coulang, ..	5.13	
Bavarian Ob-Pfalz, {	Earthy, from Grünlas, ..	1.50	Reinsch.
	" " Verau, ..	6.66	
	Lignite from " ..	10.00	
	" " Greece, ..	8.40	
	" " Usnach, ..	9.02	Regnault.
	" " Cologne, ..	2.19	
	Earthy brown coal from Dax, ..	5.45	
	" " Bouches du Rhône, ..	4.99	
Cassel,.....	" " Nieder-Alpen, ..	13.43	Kühnert.
	" " Stangen—coal, ..	3.01	
	" " pitch—coal, ..	15.47	
	" " Herschberg, ..	2.43	
	Pitch coal, ..	0.81	
	Middle sort, ..	2.76	
	Lowest sort, ..	3.30	
	Pitch coal from Habichtswald, ..	4.92	
	" " " ..	1.33	
	Stillberger coal, Söhrwald, ..	3.33	
* From Düren, on the left bank of the Rhine,.....	Lignite from Hirschberg, ..	6.95	Karsten.
	" " Iceland, ..	1.25	
	" " another specimen, ..	8.80	
	" " Utweiler, ..	27.50	
	" " Grube Urwelt, ..	0.90	
	" " " ..	4.60	
	" " Friesdorf, ..	27.05	
	" " " ..	1.69	
Near Boom, on the right bank of the Rhine,.....	" " Putzchen, ..	14.90	Varrentrapp.
	" " " ..	4.40	
	" " Stösschen, ..	17.40	
	" " " ..	14.40	
	" " Orsberg, ..	28.20	Reinsch.
	" " " ..	43.20	
	Coal from Schöningen, ..	58.00	
	" " Helmstädt, ..	7.80	
	Slate coal from Azberg, ..	8.40	J. A. Phillips.
	" " Aga Reuss, ..	6.00	
	Earthy lignite from Wigan, ..	4.95	
	" " Conception Bay, ..	7.49	
	Lignite from Sandy Bay, Patagonia, ..	13.29	Admiralty Coal Investigation.
	" " Talcahuano Bay, ..	6.92	
	" " Altern, Germany, ..	1.16	
	" " Lough Neagh, Ireland, ..	6.84	
	" " Isle of Madeira, ..	20.05	Kremers.
	" " " ..	20.05	

Thus it will be observed, that the inorganic matters contained in brown coal or lignite vary from less than one to nearly sixty per cent. For example, the amount of ash in a species of pitch coal from Herschberg is only 0.81 per cent., while, in a variety from the bank of the Rhine, it is 58 per cent. But those which contain the larger amount can scarcely be classed with fuels, as they cannot be economically used in that capacity.

except, perhaps, for the combustion of shaly matters, as in the manufacture of alum, *et cetera*. A much closer coincidence is found between the elementary composition of the organic matter in different specimens than appears in the mineral portion, as is shown by the annexed tabulated results of the analysis of several varieties, also transcribed from the able work of RICHARDSON and RONALDS:—

The annexed table exhibits the composition of American coals according to Professor JOHNSTON :—

Character and Composition of the Ashes.	Superior Anthracite, M specimen, specific gravity 1.591.	Superior Anthracite, M specimen, specific gravity 1.594.	Superior Anthracite, M specimen, specific gravity 1.60.	Buck Mountain Anthracite, specific gravity 1.604.	Summit Coal Company's Anthracite, head of Beaver Creek, specific gravity 1.614.	Summit Coal Company's Anthracite, M specimen, specific gravity 1.604.	Stephenson's Buff Anthracite, M specimen, specific gravity 1.614.	Stephenson's Anthracite, M specimen, specific gravity 1.614.	Quinn's Run Bituminous Coal, specific gravity 1.474.
Percentage of ashes in the coals,....	4.83	8.73	2.242	3.079	5.01	4.00	3.71	6.75	6.80
Color of ashes,.....	Light-buff.	Reddish-white.	White.	Reddish-buff.	Fawn.	Reddish-grey.	Fawn.	Brick-red.	Grey.
Silica,.....	53.603	45.105	43.68	45.60	54.50	50.25	50.05	50.00	76.00
Alumina,.....	36.687	37.000	39.34	42.75	34.45	38.90	39.04	38.90	21.00
Sesquioxide of iron,.....	5.590	13.000	8.22	9.43	7.50	8.75	8.75	8.00	2.60
Lime,.....	2.857	1.380	5.76	1.41	2.25	0.85	1.56	2.10	..
Magnesia,.....	1.076	2.430	3.00	0.33	1.30	1.25	1.30	0.90	..
Oxide of manganese,.....	0.186	..	..	..	..	..	..	..	..
Loss per cent.,.....	0.001	1.085	..	0.48	..	..	..	0.10	0.40
	100.000	100.000	100.00	100.00	100.00	100.00	100.00	100.00	100.00

The same elements are contained in the ashes of brown coal, though in different proportions, as will be seen from the subjoined analysis by VARRENTRAFF :—

Analysis of ashes of brown coal from Brunswick, reported contentually.	
Lime,.....	23.67
Magnesia,.....	2.58
Alumina,.....	11.57
Oxide of iron,.....	5.78
Carbonate of potassa,.....	2.64
Silica and clay,.....	19.27
Sulphuric acid,.....	33.83
Loss,.....	0.66
	100.00

Lead, copper, iron pyrites, and traces of iodine, *et cetera*, are also found in coal, but are by no means general. In fact, the traces of lead and copper are sometimes so minute as not to admit of estimation; but this is not the case with the iron pyrites. In some varieties this compound may be readily distinguished in clusters of cubic crystals, or in seams running through the mass; and, from its characteristic yellow appearance, the coals in which it is thus found are named *brassy coals*. It operates more injuriously than any of the other mineral compounds, as, during the combustion, the sulphur is transformed into sulphurous acid, which in itself is poisonous; and although it passes off considerably diluted by the other gases produced, yet it is hurtful, not only to animal life, but to many manufacturing processes, as well as to the boilers and furnaces of locomotives. When sulphurous coals are distilled, one-half or a certain portion of the sulphur is eliminated in the form of sulphide of hydrogen and sulphide of carbon, whilst the remainder is left united with the metallic base in the coke. In both cases it is the cause of much trouble and injury, as every gas manufacturer and smelter well knows. But these are not the only evils resulting from the iron pyrites. When coals containing it in large quantities are stored, and are affected with moisture, it not unfrequently happens that spontaneous ignition sets in in consequence of the bisulphide being converted by

its oxidation into sulphate of iron, and generating at the same time as much caloric as determines the combustion of the carbonaceous matter, which ultimately may reach to a red heat. To guard against this danger, it is well to expose the heap as much as possible to a current of air, in order that the moisture may spontaneously pass off, and the entire mass be kept cool; or, if incipient combustion has already set in, it may be arrested by loosening and turning over the heap, so that the air may pass through it freely. This spontaneous combustion is more apt to take place in mines than in the coals even when stored, unless, indeed, they are accumulated in confined places where the temperature is somewhat elevated. Under such circumstances, aided by the presence of moisture, the coals are very liable to burn voluntarily. Although the combustion which has been going on in some mines for considerable periods, cannot be attributed to the oxidation of the pyrites, but rather to the large volumes of inflammable gases which are generated in crevices in the mass, and which are accidentally ignited, yet it cannot be doubted that, through the combined action of water and a limited supply of air, the mineral assists in developing the heat throughout. When a mine takes fire, it resists every effort to extinguish it, unless the whole working be so regulated as to admit of being flooded with water. This, however, is rarely the case, nor is it ever thought of as a provision for such an emergency; and yet it is the only effective precaution that can be adopted, for the numerous fissures in the coal, which often extend to the surface, serve the purpose of powerful chimneys, whilst other chinks co-operate with the shafts, in conveying air to the seat of the fire. Every exertion has been made to check the combustion going on in some of the British mines by the erection of dams; but, although it is believed that in some of them the rate of consumption is much reduced, it still continues.

Although the specific gravity of coals and the percentage of ash which they contain are very insufficient tests of their value as fuel, yet it is evidently important to know the amount of the combustible constituents

in different kinds. Fortunately, numerous analyses of coals have been made; and the Editor feels assured that a summary and compendious view of the most important of these cannot fail to be deeply interesting to all who are concerned in those arts and manufactures in which fuel is an object of primary considera-

tion, as well as to the scientific analyst. Accordingly, the following tables exhibit the results so elaborately worked out for the Admiralty by Dr. LYON PLATFAIR, and others, in their examination of nearly all the products of the British coal mines:—

MEAN COMPOSITION OF AVERAGE SAMPLES OF WELSH COALS.

Locality, or Name of Coal.	Specific Gravity of Coals	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coals left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Aberaman Merthyr,.....	1.305	90.94	4.28	1.21	1.18	0.94	1.45	85.0
Ebbw Vale,.....	1.275	89.78	5.15	2.16	1.02	0.39	1.50	77.5
Thomas's Merthyr,.....	1.30	90.12	4.33	1.00	0.85	2.02	1.68	86.53
Duffryn,.....	1.326	88.26	4.66	1.45	1.77	0.60	3.26	84.3
Nixon's Merthyr,.....	1.31	90.27	4.12	0.63	1.20	2.53	1.25	79.11
Binea,.....	1.304	88.66	4.63	1.43	0.33	1.03	3.96	88.10
Bedwas,.....	1.32	80.61	6.01	1.44	8.50	1.50	6.94	71.7
Hill's Plymouth Work,.....	1.35	88.49	4.00	0.46	0.84	3.82	2.39	82.25
Aberdare Co.'s Merthyr,.....	1.31	88.28	4.24	1.66	0.91	1.65	3.26	85.83
Gadly Nine-feet Seam,.....	1.33	86.18	4.31	1.09	0.87	2.21	5.34	86.54
Resolven,.....	1.32	79.33	4.75	1.38	5.07	Included in ash	9.41	83.9
Mynydd Newydd,.....	1.31	84.71	5.76	1.56	1.21	3.52	3.24	74.8
Abercarn,.....	1.334	81.26	6.31	0.77	1.86	9.76	3.04	68.4
Anthracite, Jones and Co.,.....	1.375	91.44	3.46	0.21	0.79	2.58	1.52	92.9
Ward's Fiery Vein,.....	1.344	87.87	3.93	2.02	0.83	Included in ash	7.04	—
Neath Abbey,.....	1.31	89.04	5.05	1.07	1.60	—	3.55	61.42
Graigola,.....	1.30	84.87	3.84	0.41	0.45	7.19	3.24	85.5
Gadly Four-feet Seam,.....	1.32	88.56	4.79	0.88	1.21	—	4.88	88.23
Machen Rock Vein,.....	1.297	71.08	4.88	0.95	1.37	17.87	5.85	65.2
Birch Grove, Graigola,.....	1.360	84.25	4.15	0.73	0.86	5.58	4.43	85.1
Llynvi,.....	1.28	87.18	5.06	0.86	1.33	2.53	3.04	72.94
Cadoxton,.....	1.378	87.71	4.34	1.05	1.75	1.58	3.57	82.0
Oldcastle Fiery Vein,.....	1.289	87.68	4.89	1.31	0.09	3.39	2.64	79.8
Vivian and Sons' Merthyr,.....	1.299	82.75	5.31	1.04	0.95	4.64	5.31	67.1
Llangennech,.....	1.312	85.46	4.20	1.07	0.29	2.44	6.54	83.69
Three-quarter Rock Vein,.....	1.34	75.15	4.93	1.07	2.85	5.04	10.96	62.5
Pentrepeth,.....	1.31	88.72	4.50	0.18	—	3.24	3.86	82.5
Cwm Frood Rock Vein,.....	1.255	82.25	5.84	1.11	1.22	3.58	6.00	68.8
Cwm Nanty Gros,.....	1.28	78.36	5.59	1.86	3.01	5.58	5.60	65.6
Brymbo Main,.....	1.300	77.87	5.09	0.57	2.73	9.52	4.22	55.4
Tivian and Sons' Rock Vawr,.....	1.301	79.09	5.20	0.66	2.41	8.54	4.30	58.6
Coleshill,.....	1.29	73.84	5.14	1.47	2.34	8.29	8.92	56.0
Brymbo Two-yard,.....	1.283	78.13	5.53	0.54	1.88	8.02	5.90	56.2
Rock Vawr,.....	1.29	77.98	4.39	0.57	0.96	8.55	7.55	62.50
Porth-mawr,.....	1.39	74.70	4.79	1.28	0.91	3.60	14.72	63.1
Pontypool,.....	1.32	80.70	5.66	1.35	2.39	4.38	5.52	64.8
Pentrefelin,.....	1.358	85.52	8.72	tra'ce	0.12	4.55	6.09	85.0

MEAN COMPOSITION OF AVERAGE SAMPLES OF NEWCASTLE COALS.

Locality, or Name of Coal.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coals left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Willington,.....	—	86.81	4.96	1.05	0.88	5.22	1.08	72.19
Andrew's House, Tanfield,.....	1.26	85.58	5.31	1.26	1.32	4.39	2.14	65.13
Bowden Close,.....	—	84.92	4.53	0.96	0.65	6.66	2.28	69.69
Haswell Wallsend,.....	1.266	83.47	6.68	1.42	0.06	8.17	0.20	62.70
Newcastle Hartley,.....	1.29	81.81	5.50	1.28	1.69	2.58	7.14	64.61
Hedley's Hartley,.....	1.31	80.26	5.28	1.16	1.78	2.40	9.12	72.31
Bates' West Hartley,.....	1.25	80.61	5.26	1.52	1.85	6.51	4.25	—
West Hartley Main,.....	1.264	81.85	5.29	1.69	1.13	7.53	2.51	59.20
Buddle's West Hartley,.....	1.23	80.75	5.04	1.46	1.04	7.86	3.85	—
Hastings' Hartley,.....	1.25	82.24	5.42	1.61	1.35	6.44	2.94	85.60
Carr's Hartley,.....	1.25	79.83	5.11	1.17	0.82	7.86	5.21	60.63
Davison's West Hartley,.....	1.25	83.26	5.31	1.72	1.38	2.50	5.84	59.49
North Percy Hartley,.....	1.25	80.03	5.08	0.98	0.78	9.91	3.22	57.18
Haswell Coal Co.'s Steamboat Wallsend,.....	1.27	83.71	5.30	1.06	1.21	2.79	5.93	61.88
Derwentwater Hartley,.....	1.26	78.01	4.74	1.84	1.87	10.21	3.73	54.83
Broomhill,.....	1.25	82.77	4.17	1.84	2.85	4.87	3.07	59.20
Original Hartley,.....	1.28	82.52	4.58	0.72	1.44	8.03	3.97	58.22
Cowpen & Sidney's Hartley,.....	1.28	82.52	4.58	1.69	0.73	7.97	2.33	58.59

MEAN COMPOSITION OF AVERAGE SAMPLES OF DERBYSHIRE COALS.

Locality, or Name of Coal.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Earl Fitzwilliam's Elsecar,.....	1.296	81.93	4.85	1.27	0.91	8.58	2.46	61.6
Holyland and Co.'s Elsecar,.....	1.317	80.05	4.93	1.24	1.06	8.99	3.73	62.5
Earl Fitzwilliam's Park Gate,.....	1.311	80.07	4.92	2.15	1.11	9.95	1.80	61.7
Butterly Co.'s Portland,.....	1.301	80.41	4.65	1.59	0.86	11.26	1.23	60.9
Butterly Co.'s Langley,.....	1.264	77.97	5.58	0.80	1.14	9.86	4.65	54.9
Stavely,.....	1.27	79.85	4.84	1.23	0.72	10.96	2.40	57.86
Loscoe Soft,.....	1.285	77.49	4.86	1.64	1.30	12.41	2.30	52.8

MEAN COMPOSITION OF AVERAGE SAMPLES OF LANCASHIRE COALS.

Locality, or Name of Coal.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Inch Hall Co.'s Arley,.....	1.272	82.61	5.86	1.76	0.80	7.44	1.53	64.0
Haydock Little Delf,.....	1.257	79.71	5.16	0.51	0.52	10.65	3.42	58.1
Balcarres Arley,.....	1.26	83.54	5.24	0.98	1.05	5.87	3.32	62.89
Blackley Hurst,.....	1.26	82.01	5.55	1.68	1.43	5.28	4.05	57.84
Ince Hall, Pemberton Yard,.....	1.348	80.78	6.23	1.30	1.82	7.53	2.34	60.6
Haydock, Rushy Park,.....	1.323	77.65	5.33	0.50	1.73	10.91	3.68	59.4
Moss Hall, Pemberton, Four-feet,.....	1.258	75.53	4.82	2.05	3.04	7.98	6.58	55.7
Haydock Higher, Florida,.....	1.218	77.33	5.36	1.01	1.03	12.02	3.05	51.1
Ince Hall, Pemberton, Four-feet,.....	1.276	77.01	3.93	1.10	1.05	5.52	1.09	57.1
Blackbrook Little Delf,.....	1.26	82.70	5.55	1.48	1.07	4.89	4.31	58.48
King,.....	1.300	73.66	5.30	1.68	1.58	9.06	8.72	62.4
Rushy Park Mine,.....	1.28	77.76	5.23	1.32	1.01	8.99	5.69	56.66
Blackbrook, Rushy Park,.....	1.27	81.16	5.99	1.35	1.62	7.20	2.68	58.10
Johnson and Wittington's, Rushy Park,.....	1.28	79.50	5.15	1.21	2.71	9.24	2.19	57.52
Laffak, Rushy Park,.....	1.35	80.47	5.72	1.27	1.39	8.33	2.82	56.26
Balcarres, Haigh Yard,.....	1.28	82.26	5.47	1.25	1.48	5.64	3.90	66.09
Haydock, Florida Main,.....	1.267	77.49	5.50	1.27	0.88	12.81	2.02	54.4
Wigan, Four-feet,.....	1.209	78.86	5.29	0.86	1.19	9.57	4.23	60.0
Ince Hall, Pemberton, Five-feet,.....	1.269	68.72	4.76	2.20	1.35	18.63	14.34	56.5
Cannel—Wigan,.....	1.23	79.23	6.08	1.18	1.43	7.24	4.84	60.33
Ince Hall Co.'s Furnace Vein,.....	1.314	74.74	5.71	1.53	0.96	13.52	4.04	58.4
Balcarres, Lindsay,.....	1.26	83.90	5.66	1.40	1.51	5.53	2.00	57.84
Caldwell and Thompson's, Rushy Park,.....	1.271	76.17	5.46	1.09	0.91	14.87	1.50	58.7
Balcarres, Five feet,.....	1.26	74.21	5.03	0.77	2.09	8.69	9.21	55.90
Moss Hall, Pemberton, Five-feet,.....	1.283	76.16	5.35	1.29	1.05	10.13	6.02	56.1
Moss Hall Co.'s New Mine,.....	1.278	77.50	5.84	0.98	1.36	12.16	3.16	57.7
Caldwell and Thompson's Higher Delf,.....	1.274	75.40	4.83	1.41	2.43	19.98	5.95	54.2
Johnson and Wittington's Sir John,.....	1.31	72.86	4.98	1.07	1.54	8.15	11.10	56.15

MEAN COMPOSITION OF AVERAGE SAMPLES OF SCOTCH AND VARIOUS OTHER COALS.

Locality, or Name of Coal.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Various. Scotch Coals. { Wallsend Elgin,.....	1.20	76.09	5.22	1.41	1.53	5.05	10.70	58.45
{ Wellewood,.....	1.27	81.36	6.28	1.53	1.57	6.37	2.89	59.15
{ Dalkeith Coronation Seam,.....	1.316	76.94	5.20	trace.	0.38	14.37	3.10	53.5
{ Kilmarnock Skerrington,.....	1.241	79.82	5.82	0.94	0.86	11.31	1.25	49.3
{ Fordel Splint,.....	1.23	79.58	5.50	1.13	1.46	8.33	4.00	52.03
{ Grangemouth,.....	1.29	79.85	5.28	1.35	1.42	8.58	3.52	56.6
{ Eglinton,.....	1.25	80.08	6.50	1.55	1.38	8.05	2.44	54.94
{ Dalkeith Jewel Seam,.....	1.277	74.55	5.14	0.10	0.33	15.51	4.37	49.8
{ Colonshill Co.'s Bagillt Main,.....	1.269	88.48	5.62	2.02	1.36	0.86	1.62	55.8
{ Ewlowe,.....	1.275	80.97	4.96	1.10	1.40	8.20	3.37	54.5
{ Ibstock,.....	1.291	74.97	4.83	0.88	1.45	11.88	5.99	50.8

AVERAGE COMPOSITION OF COALS FROM DIFFERENT LOCALITIES.

Locality	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Average of 36 samples from Wales,.....	1.315	83.78	4.79	0.98	1.43	4.15	4.91	72.60
" 18 " Newcastle,.....	1.256	82.12	5.31	1.35	1.24	5.69	3.77	60.87
" 28 " Lancashire,.....	1.233	77.50	5.32	1.30	1.44	9.53	4.88	60.22
" 8 " Scotland,.....	1.239	78.73	5.61	1.00	1.11	9.69	4.03	54.23
" 7 " Derbyshire,.....	1.285	77.49	4.86	1.64	1.01	10.28	2.65	59.32

AVERAGE COMPOSITION OF FOREIGN COALS.

Locality.		Specific Gravity of Coal	Carbon.	Hydrogen	Nitrogen	Sulphur.	Oxygen	Ash.
		A.	B.	C.	D.	E.	F.	G.
Van Diemen's Land Coals.	South Cape,.....	—	63.40	2.89	1.27	0.98	1.01	30.45
	Mount Nicholas Break o' Day,.....	—	57.37	3.91	1.15	0.90	9.10	27.55
	Tingal,.....	—	57.21	3.38	1.20	1.32	7.80	29.09
	Jerusalem,.....	—	68.18	3.99	1.62	1.12	5.89	19.20
	Douglas River, East Coast,.....	—	70.44	4.20	1.11	0.70	9.27	14.38
	Tasman's Peninsula,.....	—	65.54	3.36	1.91	1.03	1.75	26.41
	Schonten Island,.....	—	64.01	3.55	0.94	0.85	3.38	27.17
	Whale's Head, South Cape,.....	—	65.86	3.18	1.12	1.14	7.20	21.50
	Adventure Bay,.....	—	80.22	3.05	1.36	1.90	4.80	8.67
	Sydney, New South Wales,.....	—	82.39	5.32	1.23	0.70	8.32	2.04
	Borneo—Lahman Kind,.....	1.28	64.52	4.74	0.80	1.45	20.75	7.74
	“ Three-feet Seam,.....	1.37	54.31	5.03	0.98	1.14	24.22	14.32
	“ Eleven-feet Seam,.....	1.21	70.33	5.41	0.67	1.17	19.19	3.23
	Formosa Island,.....	1.24	78.26	5.70	0.64	0.49	10.95	3.96
Chili Coals.	Vancouver's,.....	—	66.93	5.32	1.02	2.20	8.70	15.83
	Lignite, Trinidad,.....	—	65.20	4.25	1.33	0.69	21.69	6.84
	Conception Bay,.....	1.29	70.55	5.76	0.95	1.98	13.24	7.52
	Port Famine,.....	—	64.18	5.33	0.50	1.03	22.75	6.21
	Chirique,.....	—	38.98	4.01	0.58	6.14	13.38	36.91
Patagonia Coals.	Laredo Bay,.....	—	58.67	5.52	0.71	1.14	17.33	10.63
	Talcahuano Bay,.....	—	70.71	6.44	1.08	0.94	13.95	6.92
	Colcurra Bay,.....	—	78.30	5.50	1.09	1.06	8.37	5.68
	Sandy Bay, No. 1,.....	—	62.25	5.05	0.62	1.13	17.54	13.40
	“ No. 2,.....	—	59.63	5.68	0.64	0.96	17.45	15.64

Having seen in the foregoing the ultimate constituents of the several varieties examined, and also the amount of coke which they afford when heated in close vessels, the next point that demands inquiry is the state or condition in which those elements are contained in the coal. It is the belief of many, that common coal is compounded of a carbonaceous substance like anthracite, and a bituminous one; and it would appear, from the microscopical researches which have been made, that such is usually the case. When, however, the fusibility of good coal is considered, and the homogeneous mass which it yields upon exposure to heat is closely examined, one is led to infer that the carbon is not isolated, but combined with the other constituents in such a manner as to form a definite body. Doubtless, in some species of lignite, the bituminous matter is partly distinct from the carbonaceous; this may be deduced from the considerable quantity of tar which they yield, and the friable porous nature of their coke. From many facts connected with the manufacture of gas and other products from coal, it must be evident that this substance is chiefly composed of various carbides of hydrogen, which suffer decomposition by heat, and which, from the circumstance that suitable solvents have not yet been discovered, remain unisolated. It is an authenticated fact, that the more the amount of hydrogen in a coal exceeds that of the oxygen, the more fusible is the substance, and *vice versa*; but this surplus is not sufficient to account for its fusibility; the entire quantity is concerned in producing the effect. When the amount of hydrogen is small, the coal will not be so fusible as when the proportion is larger, although, in the first case, the ratio in which it stands to the oxygen may be much greater than in the second. If the absolute percentage of hydrogen is only about two, there is little reason to expect that such a coal will undergo fusion when submitted to heat. Experiments have shown that it requires at least three per cent. of hydrogen in

the substance, with as much oxygen as will combine with half of this to form water, to render it fusible under the influence of caloric. Such a coal affords a very intumescent coke. Coals less inclined to melt than one so constituted, may contain a variable amount of hydrogen; but when the proportion exceeds one-and-a-half per cent., the oxygen will be required in quantities capable of transforming at least two-thirds of this into water. On the other hand, if the hydrogen and oxygen be exactly so proportioned in the coal as to form water, the coal will be infusible, and the coke which is left will be pulverulent. It is remarkable that many substances constituted of carbon, hydrogen, and oxygen, differ in this particular from coals; thus sugar, gums, starch, when submitted to heat, fuse, and yield a compact coke. Hence it may be inferred that whether an organic matter containing about forty-eight per cent. of carbon, with oxygen and hydrogen to constitute water, shall be fusible or not depends on circumstances still requiring explanation. When the quantity of carbon exceeds fifty per cent., the substance is or is not fusible, according as the amount of hydrogen is or is not in excess above that which is necessary to convert the oxygen into water. All woody and fibrous matters are infusible, owing to their content of carbon being more than fifty per cent., whilst the oxygen and hydrogen making up the remainder are so proportioned as to compose water; there are, however, other bodies in which the carbon constitutes from half to nine-tenths of their weight, and yet they are fusible and even volatile under the influence of heat. Such is the case with some of the resins, wax, *et cetera*, which contain a large quantity of hydrogen that assimilates itself with the carbon, giving rise either to gaseous bodies, or liquids, into which the latter largely enters. It is upon these grounds also that the explanation of the fusion of coals so rich in carbon as eighty per cent. rests.

In many branches of trade, experience has pointed out the advantages which some varieties of coals afford,

from the circumstance that the nature of their combustion is adapted to the special work assigned them. Hence the selection of gas coal, steam coal, and such like, on account of the respective qualities they possess; the former of producing large quantities of gas, the latter of yielding a high temperature, at the same time that its combustion is tardy and gradual. The first are evidently such as, when heated, enter more into fusion, as is obvious from the adoption of cannel in gas-works whenever it can be found. For generating steam, coals which are only slightly fusible, and bordering upon the nature of anthracite, are found from experience to be the best. For various other manufacturing purposes, the particular requirements of each must decide the fittest quality of fuel. In reverberatory furnaces, and such others as are constructed with the view of producing an effect at a distance from the fire, flaming coals will be found best adapted for the purpose, but not those which are apt to form a coherent cake in the grate, whereby the draught would be impeded, and the combustion be inadequate to the effect required. On the other hand, where the heat must be very intense, those coals are found to be the best which contain a large percentage of carbon, with enough hydrogen and oxygen as will generate sufficient quantities of inflammable gases to promote its rapid ignition, but at the same time not so much as will effect fusion to any considerable extent. Such is the kind required in the smelting of metals, for the working of iron, *et cetera*. This subject will be further explained when the values of fuel come under consideration.

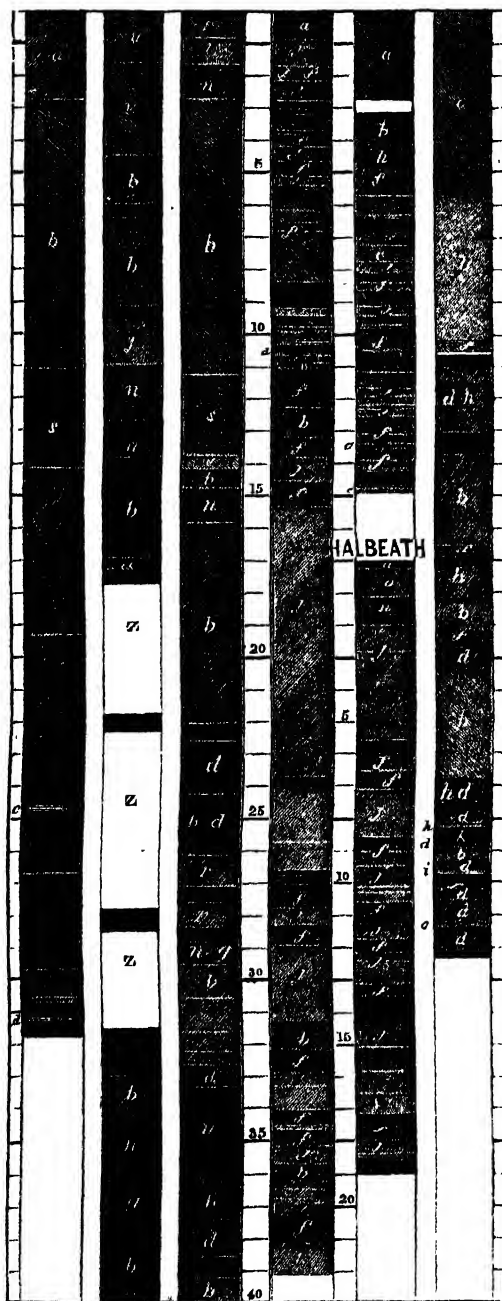
Torbanehill, or Boghead Coal.—The peculiar characters of this substance, on the nature of which geologists and chemists were much divided, attracted very great attention several years ago, and led to important legal proceedings, arising out of the following circumstances. In the beginning of the year 1850, a contract of lease was entered into between the proprietor of the estate of Torbanehill, near Bathgate, Linlithgowshire, and the Messrs. RUSSEL, Falkirk, conveying to the latter, in consideration of a fixed rent, a right to the whole coal, ironstone, iron ore, limestone, and fire-clay, on the lands of Torbanehill, for a period of twenty-five years; but the lease was not to comprehend copper, or any other mineral whatever except those above specified. In the course of their researches, the Messrs. RUSSEL had previously found an extensive deposit of the Torbanehill coal, which was shown by Dr. PENNY, in 1849, to be invaluable as a coal for the manufacture of gas. As such, it was worked and disposed of by the Messrs. RUSSEL, to whom, at the very small rent at which their right to the minerals was acceded, it promised to be a source of large revenue. In these circumstances, the proprietor of Torbanehill brought an action against the lessees for damages, laid at £10,000, on the ground that the substance was not coal at all, nor any of the minerals comprehended in the lease, and that, therefore, the lessees had no right to remove it. The case was tried at Edinburgh, before the Lord Justice-General and a special Jury, in the months of July and August, 1853, and excited intense interest, both on account of the curious scientific question involved, and the nature

of eminent professional authorities cited on both sides as witnesses. The apparently conflicting character of their testimony was also somewhat remarkable. Professor ANSTED, for instance, did not give the substance any name at all; Professor BRANDE said it was a new peculiar mineral; Professor CHAPMAN had no hesitation in pronouncing it a bituminous shale; the late Mr. HUGH MILLER characterized it as the most inflammable shale he had ever seen. Dr. THOMAS ANDERSON said it was not a bituminous shale, whatever it was. Dr. WILSON said he would call it a clay impregnated with bituminous matter, and Mr. MILNE, in like manner, called it a clay bituminated. On the other hand, Dr. FLEMING of Edinburgh, Professor GRAHAM, Dr. JOHN STENHOUSE, Professor JOHNSTON, Dr. PENNY, Dr. HOFMANN, Dr. FRANKLAND, and other equally eminent authorities, pronounced it unquestionably a coal. At the same time, the only material difference, with reference to the facts of the case, appeared in the results of the microscopical examination. The geologists and chemists agreed as to the constitution of the substance—they differed only in the name which they were inclined to give it, according to their special views of what constituted coal; but not so the microscopists, three of whom were examined for the plaintiff, and four for the defendants. Of these gentlemen, the former agreed in asserting that there was no trace of organic structure, no woody fibre or tissue—in short, no trace of vegetal matter in the substance under consideration; on the other hand, the defendants' witnesses affirmed that in every part of it there was the clearest evidence of vegetal structure; and three of these gentlemen were skilful botanists, whilst those examined for the plaintiff did not lay claim to that character. Even the microscopical evidence, therefore, was strongly in favor of the claim of the Torbanehill mineral to be considered a true coal; and this, in concurrence with the general analogies presented, induced the jury to return a verdict for the defendants. In this verdict—which quite harmonized with the opinion pronounced by Dr. PENNY before the Torbanehill coal became a subject of litigation at all—there seems to be no difficulty in acquiescing. Among the recognized true coals, there are infinite diversities in the relative proportion of the ingredients—from anthracite at one end of the scale, to cannel or parrot coal at the other; and the Torbanehill coal appears, from its composition, to be not less justly entitled to the name of a coal than anthracite, though standing at the opposite end of the scale.

In all its leading physical and chemical characters, it is identical with other varieties of cannel coal. It is unquestionably of vegetal origin. It forms a seam varying in thickness from sixteen to twenty-one inches. Its geological position does not differ from that of other Scotch cannel coals, and the associated rocks are similar to those that occur in other coal fields. In the upper part of the seam the color of this coal is brown, and the streak light yellowish-brown; but in the lower part its color is black. Fossil plants, especially stigmata of various sizes, and with numerous rootlets, are found in every part of the coal. Some are in the shape of large trunks of trees, one or two feet in diameter. The impressions of scalariform

vegetal tissue are also exhibited in almost every fractured surface. The following section of the cannel coal-fields of Scotland, by Mr. JOHN GEDDES of Edinburgh, shows the relative position of the coal, and its depth in fathoms from the surface:—

Capledras. Mulickirk. Leamihago. Inzievar and Torry. Wemyss and Methill. Torbanehill.



a. Surface.
b. Sandstone.
c. Grey bands.
d. Freestone.
e. Barling.
f. Blue.
g. Ironstone.

A. Pikes.
f. Brown stone.
j. Freestone.
k. Boghead coal.
m. Coal holding.
n. Hard band.

h. Blue clay.
i. Freestone gravel.
p. Dark grey pikes.
r. Sandy pikes.
s. Blue.
v. Limestone.
z. Various strata.

The color of this coal varies from dark snuff-brown to dull brownish-black; streak light brown; powder dull olive brown-black. It does not soil the fingers; it adheres to the tongue, and it has, when moistened, the odor of clay. It is exceedingly hard, and very difficult to break in a direction perpendicular to the plane of stratification. It is distinctly laminated, and the large rhomboidal blocks, as brought from the pit's mouth, may be readily split into thin slabs, less than an inch in thickness. Its fracture is slaty, and often beautifully conchoidal. When struck with a hammer, it gives a distinct and deep woody sound. Does not become electrical by friction. Specific gravity varies from 1.155 to 1.260; average about 1.1892.

Its microscopical characters have been ably discussed by Professor REDFERN, in the third volume of the *Quarterly Journal of the Microscopical Society*.

It readily ignites, and burns with a bright, voluminous, and smoky flame. In the open fire it splits, and crackles like other cannel coals. It does not intumesce or melt. When completely burned, it leaves a considerable quantity of fine white ash, amounting on the average to twenty-one per cent. Several cannel coals give a larger quantity of ash—page 85. The ash contains, in 100 parts:—Silica, 56.0; alumina, 43.52; oxide of iron, 0.35; potassa, 0.4; soda, 0.36; with traces of lime, magnesia, phosphoric acid, chlorine, and sulphuric acid. HERAPATH has proposed to use the ash in the manufacture of alum. This coal is not appreciably acted upon by ether, bisulphide of carbon, benzol, oil of turpentine, or naphtha. When distilled in the usual manner, it gives the same products as other cannel coals—namely, gaseous hydrocarbons, tar, paraffin, paraffin-oil, naphtha, naphthalin, benzol, ammonia, *et cetera*.

It contains every ingredient found in other varieties of coal; and there is no substance in it that does not exist in other coals. The results of its elementary analysis by Dr. PENNY, after being dried at 212°, are shown in the following statement:—

	With ash	Without ash
Carbon,	63.936	81.159
Hydrogen,	8.858	11.245
Nitrogen,	0.962	1.221
Sulphur,	0.320	0.406
Oxygen,	4.702	5.969
Ash,	21.222	—
	100.000	100.000

It yields about 67.0 per cent. of volatile matter, and 31.7 of coke. Different specimens, however, vary considerably in this respect, as shown in the following table, which exhibits the results of the analysis of four specimens taken from the pit at different dates:—

	Brown		Black	
	1849.	1851.	1851.	1853.
Volatile matters,	71.0	71.0	62.70	67.11
Fixed carbon,	11.3	7.1	9.25	10.52
Ash,	16.8	21.2	26.50	21.0
Sulphur,	0.3	0.2	0.35	0.32
Water,	0.6	0.5	1.20	1.05
	100.0	100.0	100.00	100.00
Coke,	28.1	28.3	35.75	31.52
Specific gravity,	1.1550	1.1800	1.2185	1.1882

In its chemical composition this coal is characterised by containing more hydrogen than any other variety, and by giving less fixed carbon and more ash than most other coals. Its coke, which is valueless as fuel, contains 33·4 per cent. of carbon and hydrogen, and 66·6 per cent. of ash. It surpasses all other cannel coals in its gas-producing powers. It yields from thirteen thousand to fifteen thousand cubic feet per ton, whereas the best qualities of other coals give from eleven thousand to twelve thousand cubic feet. The gas produced from

it is extremely rich in hydrocarbons, which burn with flame possessing a high degree of luminosity; hence this coal is admirably suited to be mixed with inferior varieties of cannel coal in the manufacture of gas. When distilled at comparatively low temperatures, it affords large quantities of paraffin, paraffin-oil, *et cetera*, a discovery made and patented a few years ago by Mr. YOUNG. Several interesting products have recently been obtained from it by GREVILLE WILLIAMS.

The following table will be found useful:—

MEAN COMPOSITION OF VARIOUS SCOTCH CANNEL COALS, ANALYSED BY DR. PENNY OF GLASGOW.

Locality or Name of Coal	Specific gravity.	Volatile matters.	Fixed carbon.	Ash	Sulphur	Water.	Coke.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1. Rochsoles—1851,.....	1·448	53·7	4·9	38·8	1·6	1·0	43·70
2. Hardie's—1852,.....	1·420	34·0	4·0	58·4	*	3·6	62·40
3. Boghead, <i>Broom</i> —1851,.....	1·160	71·06	7·10	21·2	0·24	0·4	28·30
4. Boghead, <i>Black</i> —1851,.....	1·2185	62·7	9·25	26·5	0·35	1·2	35·75
5. Torbanehill—1853,.....	1·1892	67·11	10·52	21·0	0·32	1·05	31·52
6. Boghead—1849,.....	1·1550	71·3	11·3	16·8	(·31)	0·6	28·10
7. Bathville,.....	1·201	61·35	12·6	22·2	0·25	0·60	34·80
8. Stand—Airdrie,.....	1·4647	52·08	14·77	32·0	·	1·15	46·77
9. Methill,.....	1·3002	49·23	17·57	29·7	*	3·50	47·27
10. Capeldrae,.....	1·3603	45·73	19·97	31·5	*	2·80	51·47
11. Wemyss,.....	1·1831	58·52	25·28	14·25	*	1·95	39·53
12. Balbardie—1852,.....	1·420	38·96	29·66	28·0	0·38	3·0	57·66
13. Hillhead—Kilmarnock,.....	{ 1·602 } { 1·320 }	36·65	32·34	27·4	0·61	3·0	59·74
14. Brymbo,.....	*	32·10	36·4	29·4	*	2·1	65·80
15. Lesmahagow—Auchinheath,.....	1·1980	56·23	36·7	4·3	0·55	2·22	41·00
16. Bartonshill,.....	1·280	46·0	39·6	10·0	2·0	2·4	49·60
17. Bartonshill,.....	1·350	38·0	37·9	18·7	2·2	3·2	56·60
18. Stevenson—Ayrshire,.....	1·3850	40·21	40·14	19·35	*	0·3	59·49
19. Lesmahagow—Southfield,.....	1·228	49·34	40·97	6·31	1·35	2·0	47·31
20. Knightwood,.....	1·234	44·7	41·13	11·05	*	3·05	52·18
21. Cairnbroe,.....	1·247	42·83	42·67	8·50	*	6·0	51·17
22. Skaterigg,.....	1·252	49·32	44·83	2·50	*	3·35	47·33
23. Cowdenhill,.....	1·299	46·0	45·0	5·0	0·50	3·50	50·00
24. Breadisholme,.....	1·335	39·0	48·5	8·1	0·4	4·0	56·60
25. Ruthill,.....	1·223	45·73	49·27	2·5	*	2·5	51·77
26. Kelvinside,.....	1·231	40·17	53·42	1·9	0·21	4·3	55·32

* Not estimated.

COKE.—Like wood and peat, coal has been found unadapted for many purposes in its natural state; either the heat which it evolves is insufficient from the presence of water and other ingredients, or the same effect is produced by the tendency of most coals to fuse and form a coherent mass, whereby the air is excluded, and the combustion impeded. Although the latter is the most frequent cause of failure, both contribute to render coals inapplicable to the wants of many of the arts and manufactures. To obviate these difficulties, and to bring the coal to a state in which it will yield the greatest possible amount of heat, recourse has been had to carbonization, the idea being borrowed, doubtless, from the advantage gained by a similar treatment of wood. By this operation, the principles of which have been already explained, the volatile products are expelled, and the liquid bodies decomposed, so that their carbon becomes to a great extent fixed, whilst the hydrogen and oxygen are dispersed. These volatile matters are utilized or not, according to the circumstances and the locality in which the carbonization is carried on. Thus, when the operation is conducted in large towns, the gases become not only a source of profit to the persons engaged in the trade, but of comfort and safety to society by their illuminating power. In

localities which are not populous, or which are far removed from cities and towns, these valuable products are permitted to pass off, not only uselessly, but often injuriously to animal and vegetal life. In either case, the fixed matter left is known as coal-charcoal or coke.

The charring of coals is conducted under these circumstances with very different objects. In towns, the coke is, in fact, only a secondary product, and is little regarded in comparison to the volatile matters, whilst in those places where the coal is burned on the field for the smelters and for locomotive purposes, all the value is attached to the solid body remaining. These latter—the iron trade and steam locomotion—are the principal sources of consumption of this kind of fuel; and since the introduction of both upon an extended scale, the inventive genius of scientific men has been exercised to discover methods of carbonizing the coal, not only more rapid in action, but also more effective, and calculated to produce a substance as much as possible divested of the volatile bodies which diminish its heating power. It could scarcely be expected that a subject so interesting as this, so important to many branches of manufacturing industry, and consequently so well meriting the attention of intelligent

While the absolute and relative yield of these products depends chiefly on the composition of the coal, the method and management of the operation to which they are submitted exercises a marked influence. Thus it may be seen practically that the products differ to the extent of several units per cent., according as the heat applied in the charring is low and gradual, or elevated and rapid. In the amount of coke, which constitutes by much the largest product, or more correctly, the residue, the observed variation from this cause is sometimes so high as six per cent., but generally it ranges from three to four per cent. It is not only in quantity, however, that the mode in which the heat is applied produces a marked effect, the quality is liable to not less variation from the same cause. By the application of a low prolonged heat, gradually raised till it reaches the strongest red heat towards the completion of the carbonization, the coke is more compact, from the circumstance that the fusion of the coal is more perfect under the gradually increasing temperature, than if the latter were applied suddenly in full force. As a general rule, these matters are little attended to in the British coke districts; the coal employed being so bituminous as to yield, under either of the conditions above stated, a compact mass, which can endure the effects of charring, & cetera, without sustaining much injury.

The several methods in use for the charring of coal, for whatever purpose, may be comprehended under three heads: namely, distillation in close vessels; heating in open heaps; and a method in which the principle of both is to a certain extent brought into requisition.

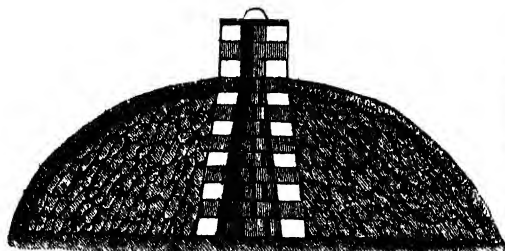
Of the first mode it is sufficient to say, in addition to what has been already stated, that the coke so produced is not only limited in amount, but is of such a nature as to render it inefficient where a very compact dense fuel is required, as in the iron furnaces and the like. Indeed, when close distillation is resorted to, the coke is less an object of consideration than the liquid and volatile products; and, therefore, it will be more in keeping with the Editor's plan to speak of it hereafter under the article GAS. By the second method, the advantage is gained of preparing a large quantity of the fuel in a short time; but at the loss of considerable quantities of material, as will be seen afterwards. The third method in which a furnace of a special form is employed, and which admits of operating upon a large quantity of coals at once, is that which is daily becoming recognised as the most economical, for it operates quicker, with less loss, and requires less attention than the others.

Coking by the second method, or the open heap, requires nearly the same operations as the carbonization of wood, only that the mounds are not so large, and they require less attention. Two systems are followed, the one characterized by the round heap or pile process, and the other by the coals being arranged in rows or ridges. For the purpose of coking in heaps, a level plot of ground is selected, the area of the heap marked out, and the coals piled upon it, placing the larger pieces at the base, and so on to the top. Fire is then applied in a cavity of about a foot in diameter, which is formed in the top for this purpose, and the

carbonization allowed to proceed. In a short time the entire mass is covered with the fire, owing to the combustible gases which are discharged, and which, igniting, conduct the fire over the whole of the coals, at the same time that they prevent its loss by shielding the heated solid carbonaceous matters from contact with oxygen. When the whole mass is at a red heat, or nearly so, and the dense heavy smoke which is emitted as long as the decomposition of the volatile ingredients in the fuel is actively proceeding has ceased, a light coating of coke ashes, or the rubbish which has accumulated, is thrown on, and the air entirely excluded. Sometimes the mound is covered with straw, dried leaves, or brambles, and coke dust or clay, before it is ignited; but this is not generally thought necessary, as the density of the coal and the downward progress of the fire, till it reaches the base of the heap, are sufficient protection against any greater loss than that which it would sustain even when covered. The period of charring a heap of twelve to sixteen feet in diameter, and two and a half to three in height, extends over two or three days before the work is finished. WILKINSON'S modification of the process, by the construction of a chimney in the middle of the meiler, so that it may serve as a draught to any portion of the mass, has been productive of great advantages in coke-making, and has, with slight modifications, been adopted in Staffordshire, on the Clyde, in Scotland, and at several other places. This appendage to the meiler is usually of a conical form, the base being about three feet in diameter, and from one foot and a half to two feet at the top. The bricks are laid so that intermediate channels present themselves all round the pile. At the top it is solid, and closed with a lid. Its height is usually three or four feet. Around the base of this chimney the coals are piled, employing the larger pieces for the base, and putting the smaller ones on towards the top and outer surface. Several channels are fashioned in the mass from the base of the chimney to the outside of the heap, through which a supply of air traverses to the region of combustion. The preliminaries being effected, and the heap coated with powdered coke or rubbish, fire is introduced at the mouth of the chimney, either by means of ignited coals or wood. The calorific which is evolved laterally through the openings in the chimney, very soon ignites the coal adjoining, and the heat extends gradually outwards to the circumference as the charring advances. As soon as the thick heavy smoke from the chimney is replaced by a lambent blue flame, it is significant that the fire has traversed the entire mass. It is now watched till the azure flame abates, at which time the draught of the chimney is cut off, by depressing the cover, and filling any chinks or cracks in the coating with fresh material. After the lapse of a few days, the process is finished, and the coke is ready for drawing. Fig. 57 represents an elevated section of this mode of charring, showing the chimney and the draught holes opening in all its circumference, and thus offering a flue for the volatile products to pass away. Sometimes this kind of meiler is ignited at several parts at the outside, near the channel flues at the base. In a short time the fire will reach almost to the centre. A few air or vent holes may now

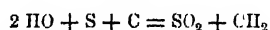
be made in the covering, by thrusting an iron bar into the heap. The smoke and other volatile compounds issue

Fig. 57.

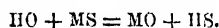


partly by these, but care must be taken to frequently renew the perforations, as, when the coals are very bituminous, the fusion of the mass is apt to choke them up. In about twelve hours or less after ignition, the fire will have spread over the whole heap, which may then be loosely covered with coke refuse, ashes, *et cetera*, leaving the vent or chimney still free. During two or three days the smouldering proceeds, by which the volatile portions suffer distillation, and are emitted by the orifice last mentioned, and the cooling will have advanced so far as to allow of the coke being used. By this mode of permitting the whole heap to get ignited before covering, and subsequently leaving the chimney open, the elevated temperature is retained sufficiently to carbonize the mass, and at the same time a waste of coke is avoided; moreover, another important advantage is gained in the expulsion of much more sulphur than could be effected if the air were more freely admitted during the operation.

It deserves also to be mentioned, that the coke manufacturer, by constructing the miler upon a moist ground, effects a purification from the sulphur by means of the vapors arising from the soil, and passing through the red-hot mass. In this case the water must suffer decomposition, its oxygen passing over to the sulphur, so as to form sulphurous acid, and the hydrogen constituting, with the carbon, light carbide of hydrogen, thus:—



When the sulphur is united to a metal, and the aqueous vapor transmitted over it, the following changes are more prevalent, assuming M to represent the metal in combination:—



If, however, the heat be too great, or more air than is requisite be permitted to pass through the mass, this decomposition will not take place, and the sulphur in great part remains. The same end might be obtained by suffusing the ground with water before forming the heap.

It should be remembered, however, that in this case, as in the charring of wood, in proportion as watery vapor traverses the incandescent mass, so a loss of the carbonaceous substance is sustained. This will be evident from the above formula; but the importance of having the sulphur removed from the coke, especially when destined to be used in the smelting of iron,

is much more thought of than the advantage of obtaining a large product.

For the most part it happens that the circular mound, notwithstanding the assistance which the central chimney affords, is too massive and solid to allow the heat to operate with its fullest effect upon the coals. The want of this distribution of caloric is supposed to be the cause of the coke retaining more or less hydrogen and oxygen, which injure in some degree its value. To remedy this, the method of *coking in rows* is resorted to. A site is marked out, the extent of which depends upon the amount of coke which is to be prepared. A line is stretched along the length of the plane, in the middle of the space which the ridge is to occupy. At the distance of seven or eight feet apart, stakes, six to eight inches in diameter, are fixed in the ground. Large pieces of coal are then laid at each side of the string, and inclined to one another, so as to leave a channel in the midst. To insure greater strength to the walls, if the first rows may be so termed, the plane of cleavage of the coal should form a right angle with the length of the heap. Other layers of coal in proportion to the size are placed beside and upon the first two, using the largest coal first, till the row is sufficiently high and wide, taking care that air channels are left at intervals in the base. The usual height to which these ridges are raised is about three feet. When completed, the whole is covered with coal dust or cinders, and fire applied at several parts adjoining the air channels; the stakes are likewise drawn, and live coals thrown into the vacant space which they leave. In a short time the whole mass will be in a state of active combustion. As soon as the heat has penetrated to the centre, the pile may be covered more closely, leaving the portion left void by the stakes as free as possible, so as to perform the office of a chimney. In case these should get choked by the fusion of the coal, they must from time to time be cleared by thrusting a bar of iron into them, or into any parts where the combustion is dilatory. As soon as the white flame resulting from the combination of the carbide of hydrogen disappears, and is succeeded by a lambent bluish blaze, all the orifices are closely covered, and the whole is left to cool.

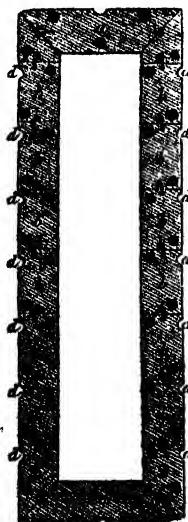
Such is the simple mode of coking in heaps and rows, but it may be remarked that particular modifications are required according to the kind of coal which is to be carbonized. Thus, when there is a large portion of fusible matter in the coal, care must be taken that the draught holes or flues are sufficiently wide to admit of the increased volume which it acquires by the effects of the heat upon it, without being closed thereby; the fire, also, must be allowed to spread over the whole heap, as well interiorly as exteriorly, before it is partially covered with the refuse matter. When, by a closing of the draught or flue holes, air is prevented from entering to the heart of the mass, considerable time may elapse, and much of the exterior may be consumed, before the interior portions are charred; and it not unfrequently happens that while the outside of a ridge is completely coked, the interior is left intact. As an auxiliary to the process, when very bituminous coals are operated upon, the fire should not be kindled in the chimneys or spaces left by

the stakes till the base be well ignited; the facility which these afford for the escape of the products of combustion will expedite the process, and the result will be the general charring of the heap, whereas, if these precautions were not taken, the work would be but partially performed. The same observations will apply when the coal is small, and, therefore, forms a ridge which is less impervious to air. In the latter case, instead of stakes being driven into the centre, brick chimneys are erected, as in the meiler system.

Where there is great demand for coke, and the area admits of the construction of a large heap, one portion may be undergoing carbonization, whilst the other is being constructed, and thus the process of coking may be rendered continuous. The method of charring in ridges is preferred in most establishments where furnaces are not erected, as it affords a better coke, and is more expeditious than the other method. Among the more recognised benefits are the partial purification from sulphur, which arises, as has been stated, from the fact that the steam which evaporates from the base of the heap passes over the coke whilst at a red heat, and operates as already mentioned; hence, to insure this, it is customary, wherever practicable, to cut a dyke around the carbonizing plot, the water from which keeps the ground always damp. Besides the advantages which accrue from the floor of the heap being moist, the water is always required to arrest the too rapid combustion which is apt to take place in some parts of the ridge, and also to extinguish the incandescent charcoal when it cannot be allowed to cool spontaneously.

A modification of this method of coking has been followed for some time at the Janon Works, near Saint Etienne, in France, and is useful for economising the rubbish, slack, or small coal which could not be worked in the manner detailed. It is evident that the

Fig. 58.

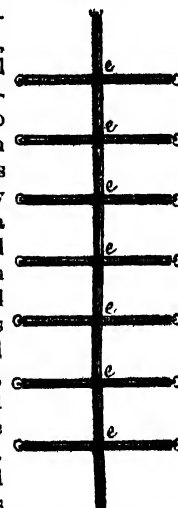


adoption of some similar plan at many of the British collieries, where considerable quantities of coal of average quality are allowed to go to waste, would be highly advantageous. The heaps or ridges which are constructed at the establishment alluded to, are almost of the same dimensions as those formed with large coal, and, like the last mentioned, may be either of an oblong or conical form, according as the ground affords the necessary facilities. To construct an oblong ridge, a board, *a*—Fig. 58—is placed in an inclined position, suited to that of the heap, and resting on two iron levers sunk in the ground. Against this are fixed other boards, *b b b*, one over another, and secured by levers or bars of iron sunk in the ground at regular distances apart, and iron hooks. After the sides are ten or twelve feet in length, the prism is provisionally closed by a board, *c* similar to

the first. All these boards are perforated, in order that conical stakes may be introduced to the interior through them, for the purpose of yielding ingress to the air in the spaces which are left after the latter are removed.

The arrangement of the lower conical stakes, by which these internal air spaces are formed, is seen in the annexed Fig. 59, where the stakes are represented in the position they would occupy when passing through the lowermost series of holes, *d d d*, in the walls of the ridge. A large stake, running longitudinally in the middle of the prism, forms the principal one. Upon this other smaller ones are fixed, as at *e e e*, perpendicular to it. These being adjusted, or in readiness, a layer of the small coal, moistened to give it consistency, is thrown in till it rises to the level of the central stake, when the vertical ones are arranged as already stated, and a fresh quantity of coals added. By means of a heavy beater, the mass is rendered as compact as possible. A fresh layer of the slack is added, and beaten down as before, till the mass rises to the level of the second range of holes in the side boards, when horizontal stakes are laid from them, so as to abut against the vertical ones at a slight inclination. After the coal has been arranged in the same manner till it reaches

Fig. 59.



the third level, another series of rollers is laid down as before, only that it is not requisite they should be set obliquely. All these posts are generally three or four inches in diameter, and have a ring in the outer end to facilitate the drawing after the heap is formed. At this period the vertical stakes are drawn out, and then the side ones, beginning with those uppermost, and proceeding to the lowest. When this is done, the boards forming the walls are taken down and laid in continuation of the ridge, and the same order and operations are followed. In this way the prism is extended to any required length, but usually it terminates when it reaches from fifty to sixty feet in length, or even less than this, according to circumstances.

Ignition is commenced by lighting some round coal, placed at set distances in the upper holes, as well as in the middle of the heap. Care should be observed that sufficient space is left for the air to traverse these channels. In a short time the fire gains sufficient strength to ignite the whole heap gradually. As this is being attained, attention must be directed to the openings, that they do not become closed through the swelling of the mass, and, likewise, that cracks or fissures forming in the exterior are immediately closed with refuse coal. After the whole mass has become incandescent, and the evolution of whitish flame has ceased, water is poured into the lower longitudinal tunnel. By the conversion of this fluid into steam, and its passage through the mass, a further quantity of hydrogen and oxygen is expelled, as well as some

sulphur. When this operation is performed, the fire is extinguished by suffocation in the usual way. From six to ten days are required to complete the operation, and the coals afford half their weight of coke of fair average quality. It is evident that only caking coals are capable of being charred in this manner, as the non-bituminous varieties would not remain compact enough during the period of the firing.

The only drawback to this method, is the considerable consumption of coals which is necessary to ignite the mass, and which amounts to one-twentieth of the whole. By constructing the heap of a conical form, this may be reduced by one-half. It is done by an arrangement of boards, secured as in the prismatic heap, presenting the form of Fig. 60, and including a space of ten or twelve feet in diameter. A square stake, *a*—Fig. 61—is fixed in the centre of the pile, against which lean six conical stakes, *b b b*, placed at equal distances. The latter are perforated in the sides and upper part, for the purpose of receiving other stakes, *c c c*, which assume a vertical and horizontal position to each of the six principal ones. Coal is thrown in, and well rammed down, till it rises about three inches above them, when another series of stakes is laid down similar to the foregoing, only that the smaller stakes leading from the six larger ones are not directed above the preceding, as may be seen from the position of the holes in the larger ones. Another layer of coals is then laid on, and this course is pursued till the pile has risen to a height of three feet and a half, with a diameter of seven at the top. A number of smaller chimneys is

Fig. 60.

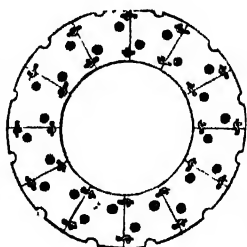
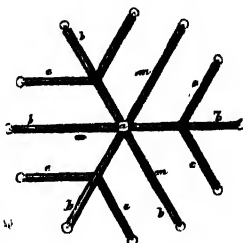


Fig. 61.



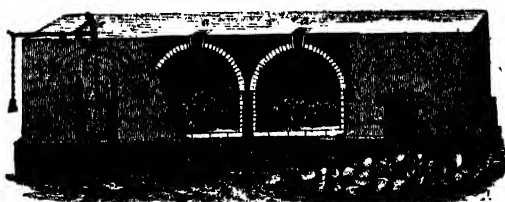
constructed by fixing, in the first series of stakes, vertical ones at the points, *m m m*, which rise higher than the top of the pile. In the subsequent details of pulling out the stakes and igniting the heap, no material difference exists between the method already described and that under consideration; the particulars of the carbonization are likewise the same in each. In this way much of the fuel which would otherwise be unsuited to such work as the smelting of metals, or for railways, is made to answer the same purposes as the best coal, and at little expense.

Another system to which the coke manufacturer has recourse, is that of heating in ovens. In this case the heat employed for effecting the carbonization is generated within the oven or furnace, and at the expense of a portion of the fuel. Were this not so, the product would be wanting in the necessary density and compactness for the iron furnaces, and, like the coke from the gas-works, would not be adapted for generating

high degrees of temperature. The method of coking in ovens is practised also for economy, as not only yielding a larger product of coke, but affording the means of recovering some of the products of the distillation. It is not, indeed, without its inconveniences, more especially if the coals be very much charged with sulphur; for, in this case, the coke retains that injurious element in much larger quantities than if the carbonization were effected in the open melter. The ovens, however, can hardly be excelled for the production of a hard dense coke; and hence they are employed by several iron-smelters, especially those upon the Tyne.

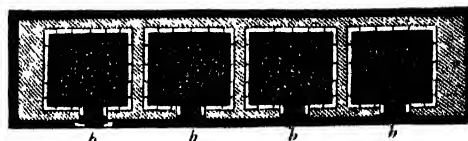
The commoner arrangement for the coking of coals in this manner, is seen in the annexed engravings—Figs. 62 and 63—the first of which shows an elevation, partly

Fig. 62.



in section, of a series of four ovens constructed in a line, for the purpose of economising the heat; and the other a plan. They have a square or oblong form, with an area of twelve feet by ten, or less, according to circumstances. The height of the furnace is also variable, differing from three to ten feet. Sometimes about twelve hundred cubic feet of coal are charred in each at once. The walls of this construction, including the fireproof facing, are about two feet thick. In the arch is an opening, *a*, two feet in diameter, through which the gases and other products of combustion pass off. No grating is supplied in this case, the air being admitted through a perforated door, *b b b*, about three feet square, in the front near the base. This door is sometimes constructed of a stout perforated cast-iron plate; sometimes it consists of a mere frame, *d*, within which bricks are laid at such distances as will leave sufficient space for the admission of air. It is movable in grooves, *c c*, by means of a main, *e*, attached to a counterpoised lever. The coals are introduced through this as well as by the superior orifice; but it is stated, that when the charge is supplied from the top, the coke is not so good as when it is deposited in the furnace through the front door. It appears difficult to assign any

Fig. 63.



cause for this, other than that, when the filling takes place from above, the central part becomes so compact as to obstruct the free passage of air through it. Before charging, if the interior be not sufficiently hot, some wood is ignited inside the front door, and

allowed to burn, and, at the first charges, the combustion is assisted by throwing powdered sulphur upon the mass. During the evolution of dense volumes of smoke, the top door is left open, and also the apertures in the door at the base; as soon as these disappear, however, both are closed, and the contents are allowed to cool. After twelve hours, or longer according to circumstances, the solid mass of coke is broken, drawn out with rakes, and wheeled off in iron barrows to a receptacle where it is cooled by sprinkling it with water. After a furnace is lighted, the first and second batch of coke which it yields is very much inferior to what is produced when it has been in operation regularly for some time; this arises from the circumstance of the base and appendages not being sufficiently heated. After a few charges have been carbonized, and the masonry has become heated, the coke has not the sponginess which characterizes the first charges; the time occupied is also shorter, and there is no occasion for adding any fire, as the heat of the base and side walls is sufficient to ignite the coal in contact with them.

An improved form of this kind of coking oven is used in the neighborhood of Pittsburg in America. This is represented in elevation and section in Fig. 64. For the most part it is constructed of bricks, and on the side of an incline, affording a facility for unloading

FIG. 64.

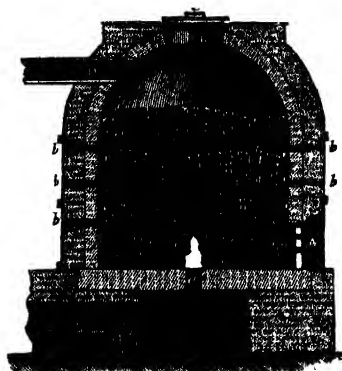


the coal on the top of the oven, and therefore erected in a position accessible by rail or common road. The hearth is oval, this form being preferred in order to avoid the inconvenience arising from the adhering of the coke to the angular parts; its area is about the same as the English ones, but the depth is only about three feet and a half, instead of being ten, as in the preceding case. In all the other details, the two methods are similar.

In many parts of Germany and France, some of the products of the distillation are recovered, more especially the tar. This economy is not so much practised in the coking establishments of England, although her maritime wants require considerable quantities of this substance. The kind of furnace or oven constructed for the charring of coal and the collection of coal-tar in Silesia, is represented in section in Fig. 65. The oven is of a cylindrical form, eight to nine feet in height, and four in diameter. Any ordinary building materials are employed in constructing the exterior portion of this oven, but the interior must be composed of very refractory clay or fire-bricks. There are two principal openings, A and B, through which the coal forming the charge is introduced: the aperture, B, is closed by nicely fitting cast-iron lids, C, whilst the former may be secured by bricks and mortar, to which

security is given by a cast-iron plate. In the bed and wall of the oven metallic pipes are laid at intervals,

Fig. 65.



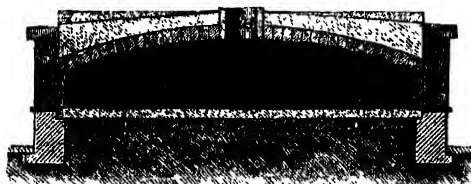
and encased with the masonry and brickwork; these serve to conduct air into the furnace for the purpose of carrying on the combustion to such an extent as will be sufficient to char the mass contained in it. They are seen at A in the base, and at B B B in the wall. All the volatile matters evolved during the carbonization are carried off through the cast-iron pipe, D, to a receiver, wherein the condensable portions are retained. In warm weather, and when work is active, this pipe is immersed in a water tank, intermediate, for the more effectually condensing the tar; but this is not required in the colder seasons. Care must be exercised in filling the oven, to deposit the larger coal upon the hearth, and so on, reserving the smaller for the upper layers. Inside the door, A, a space is left for the introduction of lighted coals or wood; but as soon as the coals have taken fire, the top door as well as the lower one are closed tightly, currents of air being circulated in the interior, through the openings in the wall and base of the oven. The upper rows of holes are closed also, the draught being instituted through the lower series, till such time as the contents of the oven have, at this level, reached a red heat. When this occurs, the orifices in the first row are closed, and those of the next opened, and left so till the fuel seen through them has assumed a red heat, after which they are closed like the foregoing, and the next opened. This process of opening the draught-holes is repeated till the whole of the charge becomes ignited. The time for changing the draught becomes pretty definite when the oven is regularly worked; thus, the coals will appear to glow, when viewed through the lower holes, in ten hours after lighting the fire, and this indicates the fit time for closing them; in about the same period, the second row may be secured in like manner; the third series remains open during sixteen hours, and the fourth only three hours. A period of twelve hours is then allowed for the furnace to cool, at the end of which time the coke is drawn. In this furnace the coals operated upon are slightly bituminous; they afford on an average about seventy-four parts by volume, and fifty-three per cent. by weight, of coke, together with rather more than five gallons of tar. The coke which is thus manufactured is very superior, in every particular, to that which

is prepared in the melter, but the course of operations is, on the other hand, expensive and slow.

In the same locality, a mode is followed for economizing the slack and other small coal, by converting it into coke; and this course of procedure is not very unlike that described for the coking of small coal by the melter system. The furnace is an oblong rectangle, with doors at each end, through which the small coals are wheeled in, and there, after moistening them with water to make them cohere, they are well beaten down. In the walls a number of air-channels are constructed, leading into the carbonizing space, and pieces of wood are laid between them, extending the whole breadth of the furnace. More coal is piled upon these, and pressed as solidly as possible till it rises as high as the wall, when it is covered with a thick layer of ashes and refuse matter. Some of these ovens are capable of charring from two to three hundred tons of coal, being about eight feet wide, five in height, and from forty to sixty feet in length. Fire is applied to the logs of wood, which have a diameter of four to six inches, and as these are consumed, they develop as much heat as serves to ignite the coal, and the space which they leave acts as a flue by which air is admitted, and the combustion extended to the whole mass. It is said that the loss sustained by the coal subjected to this mode of operation does not exceed twenty per cent.

In the vicinity of St. Etienne, and other localities in France, a coke oven is in use similar to what is represented by Fig. 66 annexed. In appearance it

Fig. 66.



resembles an ordinary baker's oven, with a low arched roof, and a flat hearth without a grate. The bed, C, of the oven, which is nearly twelve feet wide, and twenty-three feet in length, is composed of a layer of refractory clay, well beaten down, and resting upon a base of cinders or other rubbish, D, rendered as compact as possible. At each end of this oven there is a working door, A, two feet nine inches in width and two feet in height, surrounded by a framework of cast-iron fixed in the wall, and in which a small sliding-door, E, moves; there are likewise apertures, F, for affording a view into the interior of the oven; and in the centre of the arch, a space, B, about eighteen inches in diameter, is left to serve for a chimney. The height of the oven, from the hearth to the most elevated portion of the arch, is four feet. Above the arch, which, like the hearth, should be composed of refractory material, common stone, mixed with sand and mortar, serves to give the whole solidity, and to retain the heat. The charge is lighted by first heating the interior with wood, but after a few charges have been drawn, the walls and hearth are sufficiently hot to cause the combustion of the coal. The depth of coal spread

the hearth should not exceed eight inches if it be of a caking nature; but when it has little of this property, the layer may be ten inches. A little water is sprinkled on the mass to promote its caking, and the whole is rendered as compact as possible. As soon as the layer is uniformly spread, the doors are drawn down nearly to the bottom, leaving a few inches free, however, for the admission of air. At first, aqueous vapor is given off, followed by sulphurous acid and the other products of combustion; but it is found advisable to suppress the rapid evolution of the latter, and to allow the slow expulsion of all moisture, at such a temperature as will be conducive, in the presence of steam, to dehydrate the coke from sulphur. All these products pass off by the chimney in the roof. When the whole of the moisture has been expelled, the disengagement of the combustible gases becomes more voluminous, and the gases themselves more inflammable; they ignite, and a smoke of a black color succeeds the dense yellow cloud which was given off during the emission of the watery vapors in conjunction with other bodies. When the black smoke appears, the draught is increased by raising the door to the height of three inches, in order to expel the whole of the volatile products. By this means the mass is in a short time raised to a cherry-red heat. After the lapse of from half an hour to an hour, the fuliginous cloud vanishes, and the gases emitted appear whitish. At this stage the heat will have spread over the whole mass, and a contraction in the bulk will have taken place, as may be judged from the appearance of numerous cracks and fissures in the red-hot mass. In about three quarters of an hour, these crevices will have penetrated to the hearth, and the entire contents will be at a full red heat. The doors are now tightly closed, as well as all the other apertures through which air might enter, and the contents of the furnace left to complete the carbonization. It is necessary to watch the operation, lest by the admission of the air through the chimney, which is the only opening left, a loss of coke might occur. After the doors are closed, the flame and smoke still pass off, but the latter by degrees becomes more attenuated and whiter, till it nearly ceases altogether; and as the pressure in the chimney is, at this period, considerably reduced, there is evident danger of a double current being established in it; namely, an outward current of the products of combustion, and an inward one of air. To guard against this, the mouth of the chimney is gradually contracted as the pressure of gases from within becomes less, till at their disappearance it is entirely closed. Attention must now be given to withdraw the coke in such a manner as to retain as much heat in the furnace as possible. To effect this, the doors are thrown open, and the mass of coke quickly broken up with long staves, then raked out, and conveyed away in barrows to a receptacle where it is sprinkled with water whilst red hot, both for the purpose of extinguishing the combustion and removing any excess of sulphur. Another charge is introduced as rapidly as possible, and after the preliminary operations already pointed out have been gone through, the doors are closed, and the charring is again managed in the same manner. Each charge is worked off in about twenty-four hours.

Figs. 67 and 68 represent a coking furnace in use in Belgium for carbonizing coal. In these figures, the

Fig. 67.

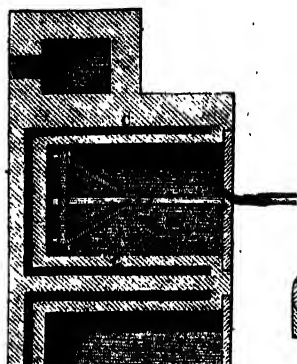
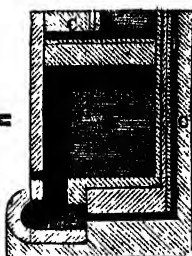


Fig. 68.



oven is represented at *n n*, the chimney in connection with this by *A*, and a flue leading to the latter by *c c*. The order of procedure is about the same in this as with the other kinds of ovens described, only that it contains a framework by which the whole of the charge may be drawn out at once when necessary.

In those ovens which work off only a thin stratum of coal, the coke which is formed is never so good as in those in which a thick bed is charred. It is more difficult, however, to carbonize the coal under the latter circumstances, and the product is less in amount. This arises from the fact, that when the mass is thick, and the coals are of a fusible nature, the air is prevented from passing up through the heap, and the result is a superior layer of coke, a middle band of charred material, and the lower layer of undecomposed coal. Even when the coal is not fusible, but contains considerable quantities of ashes, the effects are the same; for, under the influence of heat, the mass cracks into blocks of some dimensions, and the ashes which result from the entire combustion of a portion of the fuel fill the fissures, so that the draught is as effectually cut off as in the preceding instance. The portion of coke which is formed, however, is, in consequence of the prolonged heat necessary for effecting the carbonization, so compact that it claims preference in the iron furnaces to all other kinds, provided no deleterious substances be contained in it. Experience has shown that such a coke resists the pressure of the materials in the furnace, and affords a more intense heat when it comes within the region of the blast, than the looser kinds.

Fig. 69.

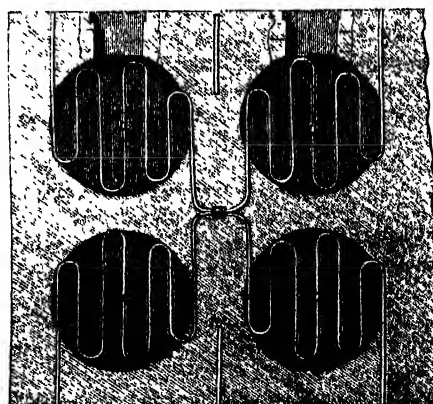


To insure the production of such a coke, a modification of the oven has been devised to enable the coke manufacturer to char from seven to ten tons at a

time. Fig. 69 represents this form of oven. It is constructed of ordinary refractory materials, and has an area of ten feet square, with a height of about four feet to the springing of the arch or dome of the furnace. To economise the heat, the arch should be so constructed that it will reflect the heat of the fire upon the coal as much as possible, and thereby hasten the carbonization. After the mass of coal has attained a red heat, and the volatile matters are expelled at the chimney, the draught-holes are tightly closed, and the mass is left to itself in this state. Under the action of the confined heat the coke contracts in bulk, and acquires a considerable degree of hardness. When the charge of coke is drawn, the floor of the kiln is cooled down to such a degree as that it will not affect the fresh charge, nor cause a partial distillation of those portions in contact with it, for the coal thus acted upon would yield a lighter and porous coke. This effect is produced by means of a winding or sinuous flue beneath the floor, as seen in *aa*, Fig. 70, which terminates in the chimney, *b*, Fig. 69.

Many other beneficial modifications and improvements are introduced where large quantities of coke

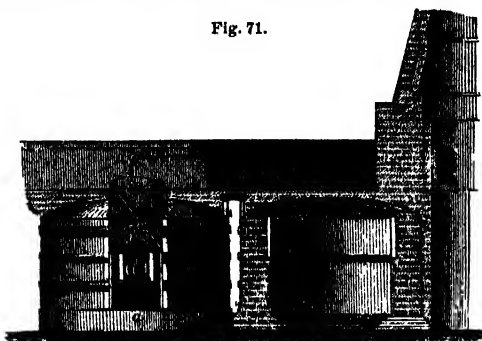
Fig. 70.



are prepared; such as collating several furnaces in a range, by which much loss in the combustion of coal is prevented, owing to the greater amount of heat retained by the materials of the furnace; expedition in charging and discharging the ovens before or after the distillation; and, not the least, the prevention of nuisances by the erection of tall chimneys, which carry the dense volumes of smoke evolved during the action of the fire high into the atmosphere, and, to a great extent, out of the range of vegetal and animal life. Several such improvements may be observed in the coke ovens established at Camden-Town for supplying the railways, especially those of London and Birmingham. Fig. 71 exhibits the disposition of these furnaces, of which there are eighteen or more in a continuous row, and all the volatile products are conducted by a horizontal flue to a tall chimney, which is placed at one end of the line. Like some of those already described, the bed of these furnaces is elliptical in form, the greater diameter being about twelve, and the lesser, ~~eight~~ feet; the walls are about three feet thick, being

lined with refractory firebrick or clay. The soles of these furnaces are constructed of solid materials, well compacted, the upper layer consisting of firebricks. In

Fig. 71.



the front are the openings, *a*, forming the charging doors, which are three and a half feet wide exteriorly, and about two feet three quarters interiorly; they are closed by cast-iron plates, *b b*, five feet and a quarter in height, by four in breadth, to which counterpoise chains passing over pulleys are appended at the upper extremity, and which facilitate the opening and closing of the door.

The draught of air passing through the furnaces, is regulated by a damper fixed in the horizontal flue; and to prevent smoke from issuing from the mouth of the chimney, a quantity of air adequate to the carbonaceous gases is introduced into the flue, so that the combustion of those products is effected. Each furnace is charged with three and a half to four tons of coal spread over the base. Fire is applied as well at the base as at the front door in the first charge; but after this is charred, and the walls of the furnaces become heated, ignition is produced by lighting some straw or brushwood under the arch of the furnace. Combustion proceeds regularly till the whole contents are at a red heat, and the entire volatile ingredients expelled. This takes place in about forty hours, at which time the dampers are closed, and the mass of coke is left to cool spontaneously, to render it more compact. After cooling, the coked mass is broken, and then drawn out by an iron rake, the handle of which moves on an iron ring suspended before the opening.

Such are the forms of furnaces adopted, and the processes usually followed in the manufacture of coke, but there are many modifications according to the nature of the coal. Some of these are calculated to afford a larger product, whilst others are intended to manufacture a purer coke than can be done by the ordinary method. The principle involved in those improvements which have in view the increase of the product, is such an equalizing of the temperature as to prevent the heat exercising an undue effect on one portion of coals, whilst another may not be fully charred. The advantage gained, however, even by the most careful management, does not, according to the researches of KARSTEN, amount, in the case of the charring of coals, to more than five or six per cent. Generally, the quantity of coke which a coal produces depends more upon its atomic constitution, and the amount of ash which it contains, than upon any other

condition; and without these data, it is nearly impossible to judge what quantity of coke a coal will yield. The analytical tables, given at pages 80, 81, and 82, will throw some light upon the amount of product from many varieties. British coals usually average from fifty-four and a quarter to about seventy-three per cent. American coals examined by JOHNSTON yield about the same quantities. In either case the inorganic constituents, which take from the heating effect of the coke, are included in the calculated amount. By deducting these matters constituting the ash from the coke, and comparing the principal combustible with the content of the original coal, the numbers will stand in nearly the following centesimal proportion for the varieties mentioned:—

	Entire content of carbon in coal	Pure coke produced therefrom
Sand coal,	75 to 80	55 to 65
Sinter coal,	80 „ 85	60 „ 70
Caking coal,	85 „ 90	60 „ 80
Anthracite sinter coal,) sand coal,	90 „ 95	85 „ 94

As already intimated, the quantity of carbon in the coal previous to charring is no certain guide to the estimation of the coke which it will produce; for some varieties, very rich in this element, but associated with hydrogen and oxygen to a considerable extent, yield but a low per centage of fixed matter after the fire has exerted its influence upon the mass. To arrive at the knowledge of how much coke any particular kind of coal will afford, recourse must either be had to an accurate analysis of the substance, or a careful observation of the actual mean produce of a number of charges.

The cost of manufacturing coke by the furnace system, averages in England about one shilling and two-pence per ton. In Belgium, the expense amounts to about two shillings and a penny, even when working the large furnaces.

Washing.—Of the improvements for the purpose of producing a better quality of coke, the method of washing lately introduced in France deserves notice. In that country, as well as in Belgium, the veins of coal are intimately blended with shaly matters near the walls, or intersected with such substances, which are in some instances harder, though in others more friable than the coal. In this state, it could not be advantageously employed for coking; and, with a view to economy, it is customary to assort the coal into three classes or qualities. This is done by means of an apparatus called a *gailleterie*, consisting of strong sieves, upon which a stream of water falls. The largest pieces, called *gaillettes*, about two cubic inches in size, are retained in the first sieve; the *gailletins*, or second size, are composed of pieces about one-third of a cubic inch; and the third, or *tails*, consist of fragments smaller than these. From the first, the pieces of schist may be easily removed by picking; but the second, in which considerable quantities of stones and other matters are retained, cannot be so purified; whilst, in the third, or tails, all the earthy, pyritous, and other friable impurities accumulate. M. MARSILLY's experiments showed that the coals from the basins of the Mons and of Valenciennes, when so treated,

and the products converted into coke, gave a result manifesting considerable difference as to quality. The first selection, or *gaillèterie*, afforded a good coke, its ashes averaging from six to seven per cent.; the coke from the next selection was not so good, and retained from seven to eleven per cent. of mineral matters. The original coal, when carbonized without any preparation, yielded a product intermediate between these. It was inferred from such results that the substances which affect the purity of the coal are those which are more friable, and that, by a proper course of treatment, they might be concentrated in the *brees* or final refuse of the coal. To effect this, the coals are subjected in some places to a process of washing, similar to that followed in the purification of minerals. In the pyritous coal localities of the Vosges, this process has been practised for a considerable period; but it was not adopted in other collieries till about 1840, when it was introduced into the coal districts of St. Etienne Rive de Gier, and at the Mons and Valenciennes.

Fig. 72.

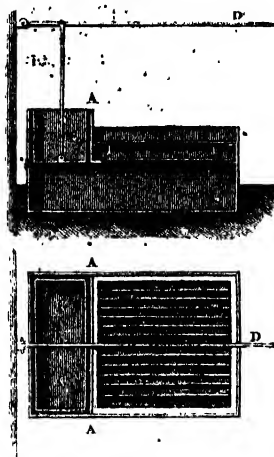


Fig. 73.

Fig. 73, annexed, shows a plan of the same. It is a rectangular wooden trough, divided into two unequal compartments by a partition, A A, which does not extend to the bottom. In the larger compartment, a grate, B B, of osiers, iron wire, or perforated zinc, is fixed, and upon this the coals are cast. The trough is filled with water till it rises to the coals on the perforated shelf, when the washing is proceeded with. This is effected by moving the piston-rod attached to a box, C, filling the smaller compartment, up and down in the water by means of an arrangement of levers, D, as seen in the drawings—a movement which has the effect of forcing the water higher in the larger division of the trough, and of floating the lighter portions of the materials, so as to cause the schistose matter to gravitate to the bottom by the motion produced by the alternate rise and fall of the water. When the action has been continued for a sufficient length of time, the superior layer of purified coal is removed from the under layer of impurities. To render this part of the work less troublesome, another perforated bottom, F F, is fixed over the grate, B B. During the washing, the pyritous and other matters fall through the first, F F, and accumulate upon the second one, whilst the purified coal still rests upon the former. Under favorable circumstances, three men can work off from twenty to twenty-five cubic yards of coal in the space of twelve hours by this machine. The water is drawn off from time to time, and supplied by a proper adjustment of stop-cocks, *et cetera*.

The apparatus employed at Commentry for washing the coal, is, on the whole, simpler than the preceding. Figs. 74 and 75 show a plan and elevated section of the apparatus. The pipe, R S, conducts the water by the connecting pipes, T T T, to the stages where the fuel is washed, and which are represented at A B C D, A' B' C' D', *et cetera*. The coals are deposited in the upper compartment of those beds, as at A B, A' B', and when

Fig. 74.

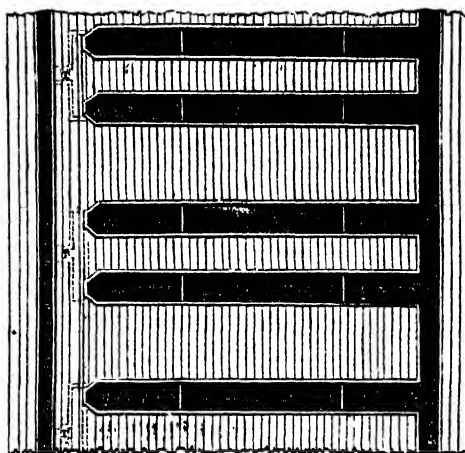
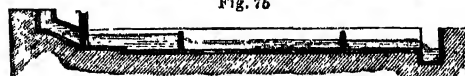


Fig. 75.



the water passes through, the larger pieces are retained by the gratings which divide these from C, C'; while those pieces which pass through the openings of the first grating are retained in the second, and so on, the water finally passing off by the exit pipe, E F. Several other machines have been tried; but the most economical seems to be that of M. BERARD, introduced about six or eight years ago, and another of a later date, invented by M. TROENLICH.

BERARD'S machine consists of an elevator, a separator, and what he terms *bancs à lavage*. The elevator is formed of an endless chain of buckets, which lift a certain quantity of the coals from the pit or trough where they are deposited. These buckets empty themselves upon the second part, or the separator. This is a long box divided into compartments by perforated plates, the perforations of which decrease as they extend from the upper to the lower part of the box. By a jiggling or shaking motion given to the whole apparatus, the lumps of coal are divided into four sizes, whilst the shaly and pyritous matters settle to the bottom. While effecting this assortment of the coal and separation of the sulphur compounds, the same movement forces out the several kinds of coal by a side opening into the third part of the machine, or the *bancs à lavage*. There are likewise long rectangular frames, nine feet two inches in length by four wide, provided with perforated bottoms, the holes in which are so small as to retain the pieces of coal thrown upon them. Like the separator, these boxes are divided into compartments, and are kept quite filled with water. In one part works

a piston, by which motion is communicated to the water, so as to cause the material to arrange itself in the order of its density. A current of water made to pass through the box, carries the purified coal beyond the box till it falls into a waggon, in which it is conveyed to its destination; the shaly matter which is left is likewise forced by the current to a trap-door, to which the bottom of the box slightly inclines, and is thus removed. It is said that by one of these machines, the cost of which amounts to about four hundred pounds, and with a daily supply of two thousand gallons of water, not less than one hundred and twenty to one hundred and forty tons are washed per day, at an expense not exceeding one penny per ton.

TROELICH's machine consists of a large circular cistern coopered in the ordinary way, and in this a wooden framework, or agitator, is made to revolve by means of an upright shaft driven by suitable gearing and steam-power. The bottom of the cistern is dished, and in the centre is a hole to which a sort of cast-iron conical pocket is fitted; the lower end of the latter is shut by a valve, opening downwards into a canal with a bottom of wire-gauze. Immediately above the bottom three pipes enter at equal distances from one another, for the purpose of supplying water; and, a little above the level of these, at one side, is a rectangular aperture provided with a valve, which opens upon another canal with a wire-gauze bottom. When in operation, the cistern is kept three-quarters full of water, and into this the coals lifted by chain buckets or otherwise fall through a hopper. The motion of the agitator causes the fragments to describe curves of more or less length, and this allows time for them to arrange themselves in the order of their gravity. Owing to the greater density of the schist and pyritic coals, they fall at once on the inclined bottom, and thence through the grating into the pocket above-mentioned, which is emptied from time to time by means of the valve. The fragments of pure coal pass out by the rectangular opening and fall upon the grating, which has an oscillating motion given to it that serves to impel the fuel to a waggon at the end, while the water filters through the grating. The power of this machine is said to be such, that, with a cistern nine feet ten inches in diameter and depth, and a working force of ten horses, two hundred tons of coal could be washed in a day. The cost of such a machine would be about four hundred pounds.

Four to five per cent. of mineral ingredients are thus removed from the coal; but still the latter retains about two per cent. of foreign matters, which, by a more careful mechanical contrivance, may be removed. The coke from this coal, thoroughly purified, commands in France a higher price, of about two shillings per ton. Even for general consumption, the purified coal is eagerly sought, as well for its superior quality as for its cheapness; because, where the coal is at a distance, the transport of six to ten per cent. of its weight of useless material increases its cost price without adding to its value. For many uses in the arts, it is of great importance to have the coal, when much mineral ingredients are contained in it, subjected

to a purifying process. This is the more needed for all such operations as require the use of coke, but in an unequal degree. For railway purposes, the nature of the ash considerably affects the quality of the coke—that is, when it is apt to fuse and run into a slag, as then it impedes the draught, besides injuring the furnace bars. In iron smelting, this property of the ash is not of so much consequence; but the presence of sulphur compounds is deleterious, producing a sulphide of iron which runs into the metal, and impairs its tenacity. Of late years, much pains have been taken with the view of expelling the sulphur from the coke, not by washing, as already pointed out, but by the addition of such ingredients as would, by inducing a double decomposition, liberate this element, or produce compounds with it which are decomposed by the heat. This is the principle upon which the patent of Professor CALVERT of Manchester is founded. He directs to add a quantity of salt to the coal in the coking furnace, proportionate to the quantity of sulphur which the latter contains, so as to expel the injurious element, and thereby obtain a coke of a superior quality. The decompositions which concur to produce this effect are:—the reduction of the iron pyrites—bisulphide of iron—into sulphur and a protosulphide of the metal by the action of the carbonizing temperature; the former of these is expelled, but the latter would remain in the coal were it not that the vapor of the volatilized salt, coming in contact with it, induces a mutual decomposition; the chlorine displaces the sulphur, the former being assimilated by the alkali metal. The chloride of iron formed is further resolved into chlorine and a subsalt, the former of which reacts upon the sulphide of sodium, producing an alkaline chloride, as well as chloride of sulphur, which is volatilized. It is thus that the coal is said to be purified from sulphur, or, at least, the quantity of this element reduced to a very small amount—even the portion which is left, being in the state of sulphide of sodium, a compound which is less liable to decomposition than the sulphide of iron, and which would be found intact in the slag of the smelting furnace, or in the ash from that of the locomotive. The coke manufactured thus, it is said, evolves no sulphurous acid when taken from the oven; neither is sulphide of hydrogen given off when it is extinguished with water in the usual way; nor is sulphurous acid generated by its combustion in the cupola or furnace. Even ordinary coke may be improved for the wants of the smelter, by adding a certain quantity of chloride of sodium in the cupola. The reaction which takes place in this case is the same as that previously explained.

As already stated, it is evident that coke, like the coal itself, will exhibit considerable difference, both in the nature and per centage of its constituents. A glance at the analytical tables, submitted at page 80, will show the causes of this difference. It will, therefore, be unnecessary to transcribe here analytical results of the composition of coke, further than may be sufficient to indicate the usual qualities supplied to the manufacturer. Of these, nineteen analyses are subjoined:—

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
Carbon,	95.51	85.85	90.53	94.21	93.41	93.05	89.87	84.82	96.42	97.60
Ashes,	2.85	12.07	8.46	5.10	5.80	5.37	8.35	14.40	2.75	1.55
Sulphur,	1.64	2.08	1.01	0.69	0.79	1.58	1.78	0.78	0.83	0.85
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.	
Carbon,	94.08	92.44	89.69	91.16	93.54	91.49	94.31	94.62	92.70.	
Ashes,	5.04	6.00	8.35	7.65	5.70	7.05	4.97	4.26	5.70	
Sulphur,	0.88	1.56	1.96	1.19	0.76	1.46	0.72	1.07	1.60	
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	

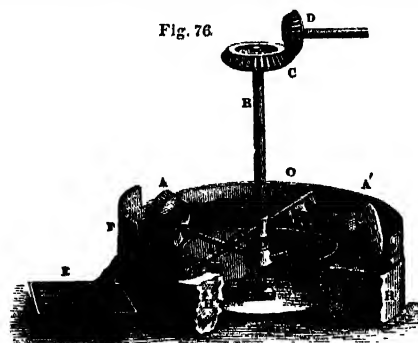
The heating qualities of coke, although easily inferred from the per centage of carbon, will be further considered when the relative value of different kinds of fuel comes to be examined.

PATENT FUEL.—In most of the operations of coal-mining, as also in coking establishments, much refuse accumulates which is frequently very rich in combustible matter; but owing to its being in small dust or powder, it cannot be used in the furnace by itself. A similar waste attends the manufacture of wood and peat charcoal, and without the aid of some cohesive matter, this considerable portion of the original fuel becomes useless.

Attention has for a long time been directed to the means of economizing such products in countries where fossil fuel is scarce, and this has not been confined to the *brees* or small refuse matter of the charcoal manufactory, but has been extended to such bodies as sawdust, wood shavings, and other combustibles. In the district adjoining the Caspian Sea, where petroleum springs are abundant, the inhabitants manufacture a fuel, by impregnating clay with the combustible fluid; the clods are afterwards burned in an ordinary hearth. By the gradual evaporation and combustion of the carbides of hydrogen, a fire of considerable intensity results. Indeed, the various contrivances which now come under the notice of the chemist, with a view to the production of artificial fuel, are little more than a copy or counterpart of the method adopted by the Orientals for solidifying the naphtha. The Norwegians have long economized the large quantities of sawdust which they produce, and convert it into a household fuel, by incorporating it with ordinary clay and a little tar, and moulding the whole into bricks. Of late years attempts have been made in this country to introduce a similar practice, by parties who proposed to employ sawdust, brushwood, shavings, spent tanner's bark, and the like substances, in the manufacture of fuel and combustible gases; but hitherto the speculation has not succeeded. The principal ingredients which are taken for the production of artificial fuel are small coal or slack, friable anthracite, the refuse or bree from charcoal and coke ovens, and peat—all of which are mixed with more or less pitch tar, or refuse fatty bodies. The product of some of these ingredients is found in many respects superior to natural fossil fuel, and may be used where the highest temperatures are required. For generating steam, a fuel carefully manufactured with small or refuse coal and pitch, or sub-

stances of a similar nature, is often preferred to ordinary steam coal, as it offers conveniences for stowage which coal does not, whilst its heating power is equal to, if not greater than, that of the mineral fossil.

In France, a very fair quality of charcoal is prepared with the refuse from the charcoal furnaces, by mixing it with other substances, such as charred peat, spent tan, and the like, adding tar or pitch. The course of procedure is to grind the solid with the fluid ingredients into a homogeneous pasty mass, which, after being moulded and dried in the air, is subjected to heat in close vessels, and all volatile gases

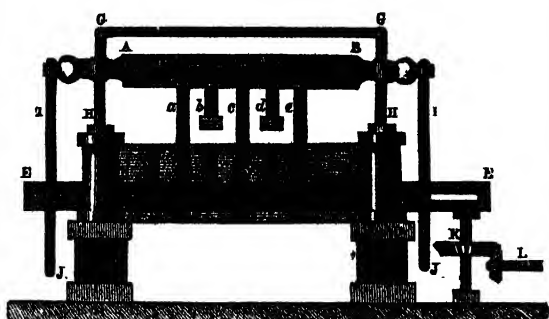


expelled. Fig. 76 represents the mill employed for mixing the charcoal, after being reduced to coarse powder by a preliminary grinding, with the tar or other liquid. It consists of two fluted cast-iron rollers, A A', connected with an upright central shaft, B, bearing a mitre-wheel, C, which is turned by a pinion, D, gearing into it. The rollers move upon the bed-plate, H H', on which the materials are laid and submitted to the action of the revolving masses till thoroughly mixed. A scraper, O, follows the rollers in the usual way, in order to bring the substances within their range, and by means of another, M, the material is discharged at the slide, F, into the box, E. About six or seven thousand gallons of the mixture are prepared by this machine in twenty-four hours, and the force required to work it is calculated as one horse. From seven to nine gallons of the tar is doled to about two hundred-weight of charcoal powder.

After the mixture is prepared, the pasty mass is moulded into appropriate forms by a machine such as that sketched in the annexed Fig. 77. By this machine the fuel is formed into quadrangular or circular masses by moulds into which it is introduced, and

therein submitted to pressure by means of a heavy log or beam of wood, which carries pistons that work

Fig. 77.

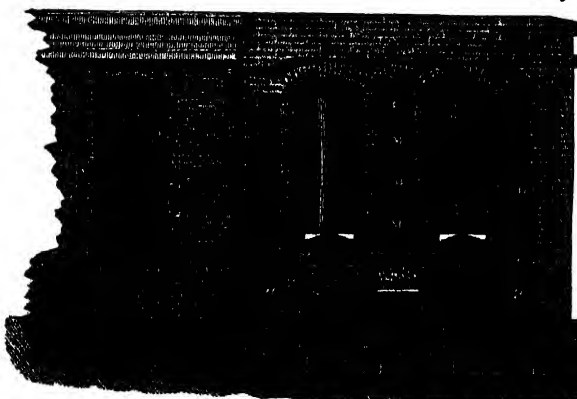


into those frames. In the above figure, the beam is represented by A B moving on the uprights, G H, G N, which keep it in its place by the eccentric motion communicated to the rods, I J, I J; a, b, c, d, e, indicate the pistons which press the material in, and discharge it from the moulds, f, f, f, f, f. Two women are constantly employed in filling the moulds; and whilst the one set are being pressed and discharged by the pistons, a, c, e, the others are replenished. When the beam, A B, is raised, the filled moulds are brought under the pistons by a horizontal motion communicated to the casting, E E, by the pinion and wheel, L, K; on the descent of the beam, these are in turn discharged, the others being filled in the meantime, and the motion of E E reversed. In this way the operation of moulding goes on without interruption. An equivalent of six horse-power is required to work this machine, but with it one man and four women can produce about four hundred and fifty bushels of the fuel in a day.

After the moulding, the next operation to which the material is subjected is the drying, which is merely an exposure of from two to three days to a current of air.

The carbonization of the bricks is effected in a kind of muffle furnace, shown partly in section, and partly

Fig. 78.



in elevation, in Fig. 78. The muffle in this furnace is about four and a half inches thick of refractory material. It is heated by a fire at B, the flame from

which circumscribes the whole of the muffle. The products of combustion pass behind the muffles by the channel, C D, but return to the front by the flue, E, and ultimately depart by the openings, f f, into the subterranean channels, g g, leading to the chimney at the back. The bricks or moulds, which are generally four and a half inches in length, by one and a half in diameter, are packed in the carbonizers, which may be sheet-iron boxes, H H H, or cast-iron cylinders, I I I; these are fixed on trucks, to facilitate their introduction and withdrawal from the muffle by a door in front of the case, lined with firebrick and refractory clay, which may be opened and shut at will. This door is shown at K, and when the carbonization is proceeding, all crevices in it are carefully stopped by clay luting.

The first effect of the heat is to eliminate moisture from the charring mass; this is followed by some carbides of hydrogen, all of which escape from the cylinders or boxes by small apertures, about the time that the cylinders are beginning to become red-hot. Air is then admitted cautiously at M, M, whereby the evolved gases are burned, giving out as much heat as is sufficient to complete the operation. By having a series of eight muffles and cylinders, two may be charged every six hours, the material being charred in a day. When no more flame is observed in the space, C, examined through M, the workman knows that the charring is completed, and the cylinders are then withdrawn.

Waste cuttings, brushwood, and such materials as could not be employed in the manufacture of ordinary charcoal, may be carbonized, and then turned to profitable account in the manner just described.

The same principle is developed in the manufacture of patent fuel from refuse coal or slack, and also from the waste matter of the coke ovens. In either case, it is necessary to mix them with substances which will give a sufficient consistency to the mass, to cause the particles to adhere whilst coking or burning in the open or furnace grate. In selecting the cementing material, there are some who do not confine themselves to oleaginous, fatty, or tarry matters, but employ also loam, hydrate and sulphate of lime, and various other mineral substances, whilst others—and doubtless this is the best course to adopt—discard the use of all such bodies; and, by a judicious admixture of two varieties of coal, or by operating upon the coal in a particular way, cause it to adhere, and so bring it into such a form as will admit of its being burned as ordinary fuel, or coke. The most important of the patent fuels will here be alluded to.

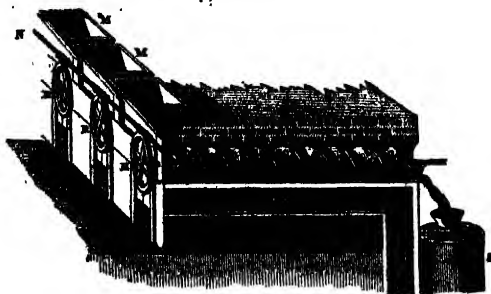
WYLAM directs, in his patent for the manufacture of artificial fuel, that small coal be mixed with pitch, and the compound afterwards moulded.

The proportions in which these ingredients are taken, are four parts of slack to one of pitch. By means of edge stones, or other machinery, the pitch and coal are ground

together, or otherwise mixed, and the mass is put into a large hopper, from which it passes into a retort. This arrangement is seen in Fig. 79, where M M

are the receivers or hoppers, from which the mixture is carried into the retort by the plain rollers, R R R, moved by the shaft, N. By the same agency, motion

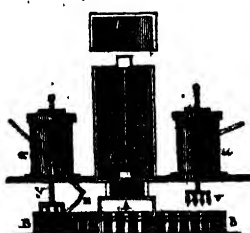
Fig. 73.



is communicated to an Archimedean screw, Q, which works within the retort, and the matter is discharged at each revolution of the screw as fast as it enters the retort from the hopper. As the retort is maintained at a red heat by the hot air in the flue, T, the material becomes more or less liquefied during the passage from one end to the other.

This pasty mass having fallen into the receiver, S, is agitated by the arms, r r—Fig. 80—to prevent it

Fig. 80.



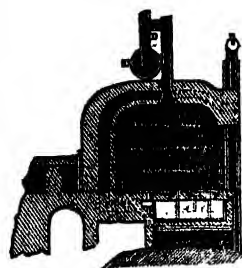
hardening into lumps before it is moulded. The moulds, B B, are ranged upon a movable oval table, A, to receive the pasty mass. Into these moulds, rams, connected by pistons, v y, are forced, by means of the pressure exerted upon them in the cylinders, u z, and which are worked by water. The table is made to revolve by means of a lever, z, by the motion which the piston, y, communicates to it; and while in its revolution the filled boxes are conducted under the rams of the piston, v, those of y discharge the formed masses into a receiver, where they are further impressed with the maker's name.

If the pitch be not well distilled, and a portion of the oleaginous constituents are retained, the fuel, when stowed where the temperature is somewhat elevated, is apt to ignite spontaneously, in consequence of the evolution and oxidation of those matters. The tendency to this is always greater when fatty matters or oils have been used with the small coal. Numerous instances of the spontaneous combustion of artificial fuels, and even of coals, have been traced to this cause. Such a disaster occurring in the hold of a vessel at sea, is almost certain destruction to the ship.

To guard against this danger, WARLICH heats his patent fuel, which is prepared nearly like the foregoing, to a temperature of from 400° to 600° Fahr., in order to dispel all the inflammable ingredients. By this means he produces a species of coke which, even in tropical climates, is quite safe. He mixes a little salt or alum with the combustible ingredients before moulding, that too much smoke may not be evolved during

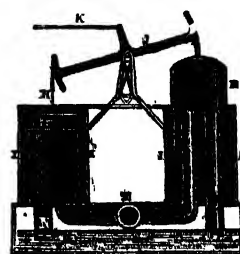
the ignition in the grate. A longitudinal section of the furnace and retort for heating and exhausting the fuel of its more inflammable constituents, is shown in Fig. 81, where A represents the retort, or the chamber wherein the fuel is heated, furnished with sliding-doors and rails, upon which the carriages loaded with the fuel run. Caloric is communicated to the matter in this chamber by means of superheated air forced in by the openings, P P, from the furnace beneath. The gaseous products are conveyed by a pipe, B, and dip-pipe, D, into a main, E,

Fig. 81.



arranged nearly in the same manner as in the manufacture of coal gas. By means of the exhausting apparatus—Fig. 82—the volatile products are drawn off. This consists of two cylinders, H H, open at the bottom, and working in vessels, I I, containing water.

Fig. 82.



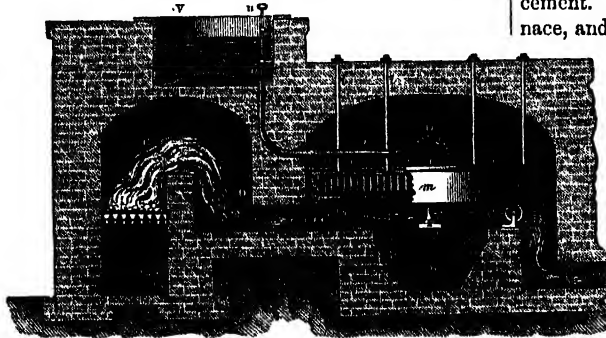
The cylinders are connected by a chain with the beam, J, and this again with the connecting-rod, K, by the motion of which the ends of the former are alternately raised and lowered, and consequently the cylinders, H H, also. At each elevation, the gases disengaged flow from the main, E, by the branch pipes, I I, into one or other of these cylinders; and as this cylinder is made to descend, the gases are forced out by the pipes, N N, which dip into the tank, O; they are secured from being driven back into the main by a valve, M M, in connection with the pipes, I I, which opens into the cylinders when the pressure is removed, and shuts when this is exerted.

At the expiration of six to eight hours the operation is finished, and a fresh charge is introduced.

At Blanz, the waste coal is worked into a patent fuel in the following manner:—The coal is screened or purified from fragments of pyritous and shaly substances, by placing the matter upon a metal sieve, fixed in a large vat, communicating with a pump by means of a large pipe. When the pump is worked, the water is agitated in the vat, and this agitation causes the matter on the sieve to arrange itself in the order of its density, the heavier particles falling through to the bottom of the vat. The principle of this washing process is precisely the same as that represented in Figs. 72 and 73. After the matter remaining on the sieve is drained, it is removed and crushed between rollers, so as to render it more homogeneous. The coal thus crushed is mixed with seven or eight per cent. of tar, and moulded into bricks. The apparatus by which this is performed is shown in Fig. 83, where B represents the furnace by which the materials are heated, and A the ashpit. D is an arch which serves to depress the flame, so that it shall pass the bridge, E,

and spread itself over an extended surface at F F, for the purpose of heating a metal cistern, *m m*, which turns on a pivot, *i*, and is moved by a pinion, *r*, working into the toothed edges, *h h*, of the cistern. A flue carries off the smoke to the chimney. The coal, when thrown into the furnace, is spread evenly by a rake,

Fig. 83.



k k, attached to rods, *l l*, that pass through the masonry of the furnace, and are secured exteriorly by nuts. A boiler, *v*, placed over the arch of the furnace holds the tar or pitch in a fluid state, and the necessary proportion may be let into the charge of coal in the furnace by a valve, *u'*, at the bottom, which may be closed at pleasure by means of the rod, *u*. From this valve it flows along the pipe, *y y*, which runs the whole length of the rakes, *k k*. In this way, a comminution of the tar and coal is effected; and when the operation is judged to be complete, two scrapers are lowered, which collect the material, and as soon as the cistern has made about two-thirds of its revolution, two trap-doors are opened, and it falls into a receptacle, *P P*, below, whence it is afterwards removed while plastic by the door, *Q*, and pressed into bricks by the hydraulic machine.

Several other patent processes for solidifying small coal and tar into a substance fit to be used as fuel, differ but slightly from the foregoing. The process of Mr. BESSEMER is considerably superior to any of these, as it enables proprietors to convert *the whole of the combustible material* into first-class coal, without suffering the loss which is invariably attendant upon colliery operations. It consists in heating small bituminous coal to a temperature at which it fuses, and while in this state moulding it into convenient shapes. By this means, the use of mineral, tarry, or oleaginous cements are dispensed with, and a fuel is produced nearly equal in heating qualities to the round coal of the working, and much more convenient for stowage, from its being in regular shapes. In this operation, a series of very ingenious contrivances are brought into requisition, and made to perform the work with admirable regularity. The apparatus by which these improvements are effected is shown in the annexed engravings—Figs. 84, 85, and 86. Fig. 84 is a longitudinal section of the furnace and retort; Fig. 85 a longitudinal elevation of the pressing machinery,

showing also the end of the furnace; and Fig. 86 a plan of the pressing machinery, with part of the furnace and retort.

In Fig. 84, the furnace, *a a*, contains a retort, *b b*, which is represented broken, to indicate that it may be of larger dimensions than here shown. For convenience of erection, it should be made of three lengths united by flanges, and the joints made tight by iron cement. One end of this retort projects from the furnace, and overhangs a part of the pressing apparatus, as shown in Fig. 85. It has a shelf or partition, *c c*, extending nearly to its whole length, and in a tangent line with the upper surface of the polygonal drums, *e* and *d*. Over the latter, two chains are made to pass, which are connected by broad plates of iron, *g*, with flanged ends, which are riveted to the single links of the chain; the edges of the plates, *g*, which project, are beveled so as to form a scraper. Motion is given to this chain by the drums, *e d*, which have projections,

i, that fall into the spaces between the binding plates, and thus carry them round the drums. On the upper side of the retort there is fixed a hopper, *j*, in the lower part of which, where the slack or coal-dust is placed, is fixed a feeding drum, *k*, with ribs or leaves

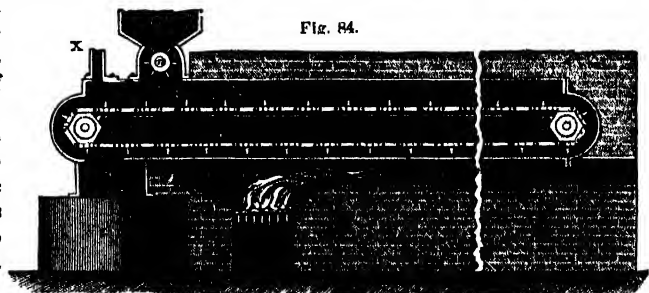
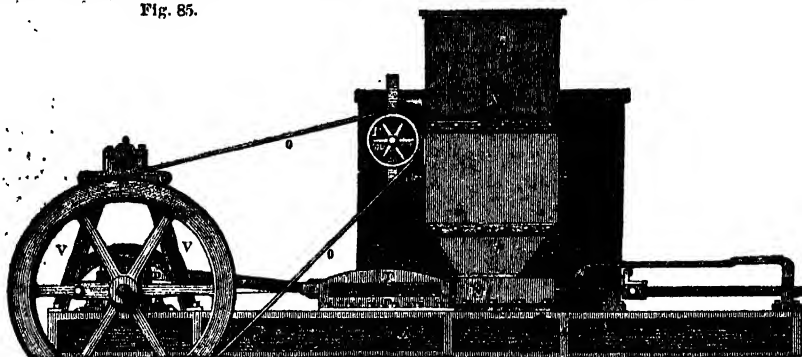


Fig. 84.

closely fitting the tube of the hopper. Appended to the side of the hopper are bosses, in which the shaft, *n*, of the feeding drum revolves. The action of this part of the apparatus is as follows:—A fire having been lighted in the fireplace, *s*, the products of combustion pass under the retort, and escape at the open end of the flue, *s'*, whence they may be conducted spirally about a boiler, for the purpose of generating the steam required to work the apparatus. When the economy of the waste heat comes to be considered, it will be preferable to set the retort so that the heat may ascend a narrow space between its sides and the walls of the furnace. An enlargement of the fire-chamber is shown at *s''*, for the purpose of transmitting radiant heat to the under side of the projecting part of the retort. The temperature of the furnace having brought the retort up to a heat approaching redness, the feeding drum is put in motion, when the small coal or coal-dust will be deposited upon the shelf, *c c*; but the motion of the chains and scrapers will move it along the shelf; and, as each scraper comes in turn under the feeding drum, the coal which has fallen between each of them will be carried forward to the right end of the shelf, off which it falls on to the lower and hotter part of the retort, occupying here

as before the space between the scrapers. It will be observed that the entire weight of the chains and scrapers rests on the bottom of the retort, and hence, by the constant passage of the former, the coal is prevented from sticking to it, and rendering its interior surface uneven. This movement not only prevents the caking of the coal to the wall of the retort, but it turns it over repeatedly, thus presenting to the heated surface fresh portions; the effect of the heat is thus equalized, and the fuel is conducted in a softened state over the opening, *f*, in the lower side of the retort, and falls into the receptacle, *t*, where it is submitted, in regular course, to compression in the apparatus, represented in plan in Fig. 86, and in elevation in Fig. 85. In these figures, *A* is the

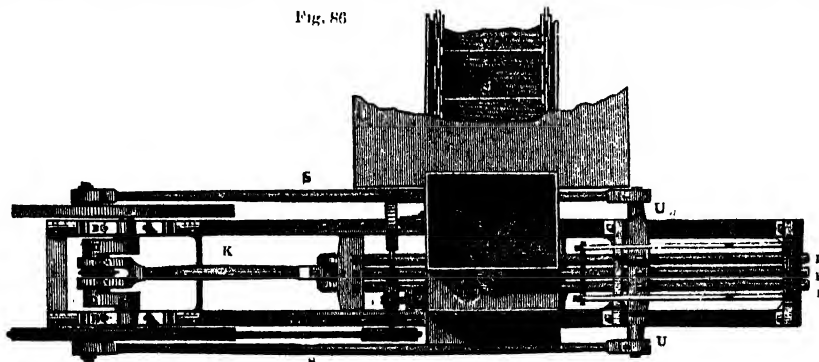
Fig. 85.



there supported by trunnions, working as usual in plummer-blocks bolted to the two frames, *v v*. In order to regulate the motion of the apparatus, fly-wheels, *F*, are keyed on to each end of the crank. A stout connecting-rod, *K*, is made with a double gib-head, *h h*, to receive motion from the same crank-throw. The other end of the connecting-rod, *K*, is jointed by a gib-head and pin to two lugs, which project from the stout cross-head, *I*; the ends of the cross-head slide in guides, *r r*, which are secured by bolts to the flange of the bed-plate. There are three plungers, *L L L*, keyed into the cross-head, and working in cylinder holes bored truly through the massive block of iron,

N, which is secured by bolts to the bed-plate by a flange, and keyed up between steps cast on the same. The upper part of the cylindrical block, *N*, has a large opening made in it, through the bottom of which the plungers, *M*, move. Immediately over this opening is the receptacle, into which the softened coal falls from the retort. Another set of plungers, *R R R*, work in the cylindrical holes of the block, *N*, at the opposite end to that occupied by *M M M*. Two guide-bars are bolted to the flange of the bed-plate, and have holes bored in them of sufficient size for the plungers, *R R R*, to work in. The latter are made large enough to work through both these guides, so that when they

Fig. 86



are entirely withdrawn from their respective cylinders in the block, *N*, they will be so guided as to re-enter them without difficulty. The plungers, *R R R*, are keyed to a cross-head, *U U*, on the ends of which are fitted, with gib-heads, two long connecting-rods, *s s*, seen in Fig. 86, the opposite ends of which are likewise

furnished with gib-heads, and work on crank-pins, which project from one of the arms of each fly-wheel. These crank-pins are so placed with reference to the central crank-throw, that the latter forms an angle of 45° with them; that is, the one is the one-eighth part of a circle in advance of the other, and thus the action of

their respective plungers will be such, that they will alternately approach and recede from one another at the end of their respective strokes.

The motion of the chain and feeding drum is regulated by passing a strap over one of the fly-wheels; this strap works on the drum, *F*, on a shaft, *m*, which carries a worm that works upon the upper side of a wheel, keyed on to the shaft of the polygonal drum, *d*, Fig. 84; another worm works into the lower side of a wheel, keyed on to the axis of the feeding drum. From this description, the reader will understand how the steam piston, acting upon its crank, will put in motion the whole apparatus, and that this motion will be regulated by the fly-wheels; also the manner in which the cross-heads will be acted upon by their respective connecting rods, and likewise how the sets of plungers, *L L L* and *R R R*, are made to reciprocate in their respective ends of the block, *N*. Supposing the operation commences when the crank, *D*, and its connecting-rod are in a horizontal position, and the plungers, *L L L*, withdrawn as far as possible from the block, *N*; if one-eighth of the revolution be now made, the plungers, *L*, will be moved forward a little, and the crank-pins will have risen to the horizontal level, and brought the plungers, *R*, nearer towards the centre of the block, *N*. Upon turning the crank an eighth further, *L* will advance a considerable distance, being at half stroke, and at the same time the plungers, *R*, will have receded to their starting position. Here it must be observed, that the soft coal which was carried forward by the plungers, *L*, is compressed between the opposing ends of the two sets of plungers. In this position of *L* and *R*, there is a small space between them where any surplus quantity of coal may squeeze out, before it is made to enter the close part of the cylinder; after which they will approach a very little nearer to each other, and thus give the final pressure. If another eighth of a revolution is now made, the relative position of the crank and crank-pins will give a quicker motion to the plungers, *R*, which will commence receding from the plungers, *L*, and thus leave no pressure on the solidified lump of coal. If the pressure were not thus relieved, the lump of coal, as it merges from its cylindrical hole in the block, *N*, would be broken, there being no longer any circumferential support for it. Another eighth of a turn will complete a single stroke of the plungers, *L*, and have entirely expelled the block of coal, which then falls down into the receptacle, *t*, the plungers, *R*, having receded still further, and allowed ample space for the block of fuel to fall.

Another eighth of a revolution will commence the return stroke of the plungers, and by following on in the same way until one complete revolution is performed, the respective plungers will again have resumed their original position, and be ready to renew the operation.

If three plungers are made use of, as here represented, three blocks or cylinders of fuel, of equal length and diameter, will be formed at each complete stroke of the engine. As there is a tendency in the block of fuel to stick to the plungers, *L*, a detaching frame is placed at the end of the machine where the blocks are expelled.

This consists of thin bars of iron, fixed on an axis, the ends of which work in lugs on the guide bar, *U U*; the other ends of the bars are connected by a rod, and upon the cross-head there are bolted two small frames, which carry rollers, upon which the bars rest. When the cross-head, *s*, moves backward, and allows the blocks of coal to be projected outwards by the plungers, *L*, then the rollers will pass under the inclined part of the bars, and descend by their own weight, and the rod will come in contact with the blocks of coal, and detach them from the end of the plungers; if they should adhere, the reverse motion of the cross-head will again raise up the bars in readiness for a repetition of the process.

From what has been before stated in reference to the softening process by heat, it will have been understood that the coal-dust may be made to traverse the shelf, *cc*, where it will receive a preparatory heating, and afterwards traverse the bottom of the retort so quickly, as to produce such a slight effect upon the bituminous portion of the coal, as only to soften it a little; and render it fit for the operation of compressing into solid lumps possessing the general properties of the coal from which it is produced. One of the objects for which these operations are performed, is to alter and modify the composition of the resulting fuel, by driving off certain of the volatile constituents of the coal, and thereby rendering such fuel more fitted for certain processes in the retort than ordinary coal. To effect this object, the speed of the feeding and polygonal drums may be adapted so as to subject the coal to any assigned period of operation, and the intensity of the fire being also regulated, the extent to which the distillatory process is carried will be under perfect control. The gaseous matter eliminated from the coal, as it traverses the hottest part of the retort, over the fire-plate, *s*, will have to pass over the surface of the coal which is advancing in that direction, and help to heat it, while it also assists in transmitting caloric to the under side of the shelf, *cc*. Having contributed in this way to heat the materials, it ascends through an opening at the end of the furnace, and passes along over the coal-dust spread upon the shelf, and farther assists in heating it, and finally makes its escape through the pipe, *x*.

This pipe should have an elbow descending in the manner usually adopted in gas-works, and known as the hydraulic main. In this vessel the liquefiable portion of the volatile matters will be condensed, and the gas may be passed to a gasometer, where it may be stored for use. The fuel resulting from this partial distillatory process will be found to be less fusible in the furnace than ordinary raw coal, and consequently the caking in the furnace will be prevented. To divest the coal of as much of the volatile gases at as low a temperature as possible, an air-pump, constructed in the manner generally employed for exhausting sugar vacuum pans, is used. The pump is connected with the pipe, *x*, and by the application of steam or other motive power, the retort is kept in a state of exhaustion, which should, if possible, be equal to twenty-four or twenty-five inches of mercury in the barometer.

By this exhaustion, the liberation of the volatile gases from the cells and interstices of the fuel is facilitated.

and the residuary matter is rendered much more dense and compact when subsequently pressed. When the air-pump is used, the eduction valve must be made to communicate with the hydraulic main, so that the gaseous matters pumped out may pass off into the gasometer. Instead of applying fire directly to the under side of the retort, as shown in Fig. 84, superheated steam may be used for softening the fuel. When this plan is adopted, a set of cast-iron pipes are arranged in a furnace in the same way as is now commonly used for heating air and steam for blast and other purposes. Into one end of this series of heating pipes, the waste steam of the engine is allowed to pass, and the pipes being kept at a red heat, the steam will acquire a very high temperature, and in this state is to be supplied to the interior of the retort, to soften the coal. The retort, which may be constructed as already described, will not, in the event of steam being used, require any flue beneath it or fireplace, but it ought to be enveloped in brickwork, or some other non-conducting material, in order to retain the heat as much as possible. The steam-pipe should open into the retort at the hopper, *z*, the outlet for the waste vapor and gases being the pipe, *x*, leading to the hydraulic main and gasometer.

Besides these, several other patents have been obtained for the manufacture of patent fuel from waste combustible materials, many of which are but of little interest.

ANALYSIS OF FUELS.—Having explained, in the preceding pages, the nature of the more commonly occurring fuels, as well as the processes by which certain varieties of them are prepared, to render them better suited for particular uses, it remains only to describe briefly the methods of analysis which are usually followed when determining their constituents, and indicate the way by which their value, in point of heating effect and practical working in the furnace, may be arrived at.

There are various processes whereby the composition of wood, charcoal, *et cetera*, may be found. Many of these are so simple, that any person having only a partial knowledge of chemical manipulation, can conduct them with sufficient accuracy; several, on the contrary, require the experience of the advanced analyst to insure success. The examination, with reference to the quantities of carbonaceous and mineral matters, may be made by simply burning a weighed portion of the fuel in a tared crucible of platinum or porcelain till all blackness disappears, and only the white or brownish ash remains. The difference between the weight of the latter and that of the original substance, will give the proportion of combustible ingredients. But before an estimate of the value of a fuel can be formed, something more than the preceding is necessary; and this will be evident from the consideration of its different applications in the arts and manufactures. For instance, the charcoal or coke manufacturer is chiefly interested in the quantity of carbon which he can retain after modifying the wood, peat, or coal, by the action of heat; he has little regard to the quantity of volatile or liquid products which can be generated from them. The gas-maker, on the contrary, is mainly desirous to secure such materials as

will yield the largest volume of gas, whereas the liquid products of the distillation, and the coke, engage only a secondary part of his attention.

To find in the simplest and readiest way whether a fuel, such as coal, is best adapted for one or other of these applications, it is necessary, in the first place, to dry the weighed sample thoroughly, and to find, by again weighing it after desiccation, how much moisture it contained. The heat of a water-bath will serve for this purpose, but an air or oil-bath kept at a temperature of about 300° will answer better. Having determined the quantity of water, the weighed sample must next be subjected to a full red heat in a crucible carefully covered to exclude the air; and, for greater security, the latter is placed in a Hessian crucible, also covered, and containing calcined magnesia. The whole is then introduced into the furnace. The magnesia serves as a support for the crucible containing the substance to be examined, as well as to prevent contact with the outer vessel. The fire is raised to bright redness, and after being maintained at this temperature for an hour, the vessels are withdrawn from the fire, and the enclosed crucible taken out, wiped clean, and weighed. The loss which appears on weighing will represent the liquid and gaseous matters present, and the residue the coke or charcoal which the sample yields. If the per centage of mineral matters be already found, the quantity of carbon in the coke is estimated by deducting this per centage from that of the total amount of coke; but if the proportion of ash has not been ascertained, the crucible containing the coke is heated over a gas-lamp or in the muffle of a furnace, so arranged that a current of air shall circulate through it, till all the charcoal is consumed.

In this way, the quantity of moisture, of volatile matter—consisting of permanent gases and liquids—of coke, and of ash, which a fuel yields, is ascertained; and from them an average inference as to the value of the substance for the production of coke may be deduced, though not for gas-making, because it leaves doubtful how much of the volatile matter consists of inflammable gases, and how much of fluid products. When a very exact knowledge of a fuel is required, nothing short of an elementary analysis can be satisfactory; and this must be coupled with another, showing the quantities of the different products derived from the fuel, when acted upon by heat, out of contact with air. Even both these fail in some cases to give the information required in relation to many applications of the combustible.

By an elementary analysis, is understood the determination of the simple elements of matter entering into the composition of a substance. To enter fully into the particulars of such an analysis would rather confuse than enlighten the reader who may not be conversant with analytical chemistry, and those who are practised in organic analysis do not require a detailed description. A mere outline of the process will, therefore, be given. The first thing to be done is to rasp or abrade a portion of the substance into as fine a powder as possible. A certain weight of this powder is then to be desiccated either in the water-bath or over sulphuric acid in an exhausted receiver, or by

passing over it dry air partially heated. The loss in either case will indicate the moisture it had contained. About ten grains of the dried matter are then taken, and intimately mixed with eight or ten times the quantity of chromate of lead or oxide of copper in a heated mortar, and immediately introduced into a dry combustion tube of hard German glass. Care must be taken that the oxidizing agent, whether it be chromate of lead or oxide of copper, be subjected to a red heat immediately before its admixture with the combustible, to insure the absence of water; also, that twenty or thirty grains of dry chlorate of potassa are put into the inner part of the combustion tube, and an inch or two of the oxidizing agent, before the substance to be examined. Having rinsed the mortar with a fresh portion of the chromate or oxide, and added this to that in the tube, the latter is tapped in a horizontal position on the table, in order to form a channel in the upper part for the gases and vapors to flow over. A few fragments of copper turnings are placed in the front part of the tube, and then a little asbestos. Having introduced these, the mouth of the tube is secured by a cork fitted with a small piece of tubing for connecting it with a poised chloride of calcium tube, in which to intercept the water generated during the combustion. To the latter, another tube filled with a solution of caustic potassa, specific gravity 1.26, and commonly known as a LIEBIG'S apparatus, also previously balanced, is joined by means of a caoutchouc connector. The success of the experiment will very much depend on the connections of the various parts being quite secure. During the fitting of these parts, the tube may be placed in the combustion furnace. As soon as the several parts are carefully adjusted, a few fragments of ignited charcoal may be laid on the sealed end of the tube containing the chlorate of potassa, and after the air of the apparatus is replaced by oxygen, the combustion is commenced by applying red-hot charcoal to the front of the tube. Care must be taken that the development of gas be not too rapid, as in this case portions may escape absorption; neither, on the other hand, must it be too slow, lest a vacuum be formed in the combustion tube, causing a reflux of the solution of potassa, which would be fatal to the experiment. A steady even stream is kept up by extending the ignited charcoal to fresh parts of the tube as the evolution begins to slacken. After that part of it containing the combustible has been brought to a red heat, and no more gas is evolved, the fire is applied gently to the part containing the chlorate of potassa, so as to produce a gradual stream of oxygen gas, the combustion tube being still kept at a red heat. This has the effect of forcing over into the absorbing apparatus any carbonic acid and aqueous vapor which may remain, and at the same time insure the entire combustion of any particles of charcoal that may not have been exposed to the full heat. Finally, the closed point of the tube is broken, and a U-shaped tube containing fragments of pumice-stone, saturated with sulphuric acid in one limb, and pieces of hydrate of potassa in the other, is connected with it; suction is then applied at the open limb of the potassa apparatus, to draw over all carbonic acid and moisture; after which the chloride of calcium tube and bulbs are

detached and reweighed, and the increase in each case noted carefully, as from this the carbon and hydrogen of the substance is calculated.

The calculation is founded upon the data afforded by the composition of water and carbonic acid—namely, that nine parts of the former contain exactly one of hydrogen, and twenty-two parts of the latter six parts of carbon. All the water resulting from the combustion of the hydrogen with the chromate of lead, *et cetera*, is retained in the chloride of calcium tube, and the whole of the carbonic acid, generated under similar circumstances, is absorbed in the bulbs; hence, when due care has been exercised, the results are very accurate. Sometimes a second chloride of calcium tube is attached to the apparatus for absorbing the carbonic acid, when the amount of nitrogen in the sample is appreciable, with the view of arresting the aqueous vapor which this non-condensable gas carries with it from the potassa liquor. It will be evident, indeed, that, in almost all cases, this precaution ought to be adopted; for even when no nitrogen is contained in a substance submitted to organic analysis, the air drawn over at the termination of the combustion becomes loaded with moisture in passing through the bulbs, and so far the weight of the latter is reduced, on which account the amount of carbon found is less than the true quantity; but by attaching a second chloride of calcium tube, filled with fragments of this salt after being fused, and which should be weighed before and after the operation, and adding the gain to that of the bulbs, this error may be prevented.

Instead of compounding the substance with a solid oxidizing agent as in the manner described, it may be introduced at once, provided it has been previously dried, into the combustion tube in a tolerably coarse state, and a stream of pure dry oxygen gas passed over it. The tube should be open at both ends, one of which is to be put in connection with the reservoir of oxygen, and the other attached to the usual absorbing media. It is necessary that the oxygen be entirely free from carbonic acid and moisture, and for the greater safety it should be transmitted through a U-tube, holding in one limb fragments of fused chloride of calcium, and in the other pieces of solid potassa, before entering the combustion tube. In this process it is absolutely essential that the potassa apparatus should have a chloride of calcium tube connected with its escaping limb, otherwise the excess of oxygen would carry with it considerable quantities of aqueous vapor, and so reduce the indication from which the carbon is to be calculated. Connection of the several parts being made, a gentle stream from the reservoir is allowed to flow through till all the air is displaced. As soon as this happens, heat is applied to the tube by placing incandescent charcoal around it in the usual progressive way, the current of oxygen being still maintained, till it assumes a red heat, or nearly so, and it is kept in this state till all the carbonaceous matter of the substance operated upon is consumed. Gas may be very advantageously substituted for charcoal in conducting an operation of this kind. When all combustible matter is eradicated from the tube, the fire is slackened, and the current of oxygen maintained for a short time. The parts for

absorbing the water and carbonic acid eliminated during the foregoing process are detached, wiped, and balanced, as already detailed, and the hydrogen and oxygen are calculated from their augmentation in weight.

To estimate the nitrogen, a second combustion is in some cases requisite. When the quantity is ascertained volumetrically, the work may be accomplished at one combustion, by establishing a connection between those parts in which the hydrogen and carbon are retained as water and carbonic acid, and an apparatus for measuring the gas. A long combustion tube is required in this instance, so as to admit of a few inches of it being filled with copper turnings, to decompose any binoxide of nitrogen which may be produced during the action of the heat. The nitrogen traverses the chloride of calcium tubes as well as the potassa bulbs, and finally enters the graduated tube, and displaces the mercury with which it is filled. When the operation is finished, some oxygen is generated from the chromate of potassa, in order to force over all the nitrogen and other gases remaining in the apparatus. A portion of this oxygen enters the graduated jar or tube, and must be removed before reading off the volume of nitrogen. For this purpose, after reading off the volume of mixed gases, a quantity of hydrogen equal in bulk to this mixture should be added, and as soon as diffused a measured portion should be transferred into an eudiometer, and exploded by the electric spark. By noting the reduction in the portion taken, the quantity or volume of oxygen in the whole may be ascertained, from the knowledge that one-third of the decrease is oxygen. Deducting the volume of oxygen thus found from that of the mixed bulk of oxygen and nitrogen, the remainder will be the volume of the latter in the portion of the substance submitted to combustion, and from which the weight is deduced, since, at a barometric pressure of thirty inches and a temperature of 60°, the weight of one hundred cubic inches of nitrogen is 29.2914 grains.

WILL and VARRENTRAP's method is a considerable improvement upon the system of analysis pursued in the determination of nitrogen, inasmuch as it dispenses with the use of mercurial troughs, graduated measures, barometers, thermometers, *et cetera*; it is besides much simpler and less laborious, for whilst numerous corrections have to be made for temperature, pressure, and the like in the old process, by this the work is most accurately performed by simply weighing. It is based upon the property which the fixed alkalies have, of converting nitrogen, in whatever state it is contained in a substance, into ammonia, when aided by heat. The ammonia is fixed by an acid—generally hydrochloric—and subsequently in the form of ammoniochloride of platinum, which is collected, dried, and weighed, and the nitrogen calculated therefrom; 222.5 parts of the salt representing fourteen parts of the gas.

The agent used for the conversion of the nitrogen into ammonia is soda-lime, which is prepared by slaking caustic lime with a concentrated solution of hydrate of soda. The compound should be thoroughly dried, and kept in well-stoppered bottles. In the cold it does not

act upon the nitrogenous element of the substance to be analysed, and, therefore, both bodies may be mixed in a mortar, provided they are thoroughly dry, without any fear of ammonia being disengaged or loss occasioned. The ordinary combustion tube answers the purpose, and the course to be pursued is the same as that already mentioned for mixing the ingredients and heating, *et cetera*. The details of the estimation of the ammonia, quantitatively, have been already stated at page 198, Vol. I., to which the reader is referred.

The modification of this process, introduced by ULLGREN, may be advantageously noticed here. The combustion with the soda-lime is essentially the same in this as in the preceding operation; the only difference lies in the manner of condensing the ammonia adopted by this chemist. Fig. 87 represents the form of apparatus employed. In this cut, A and B are two U-shaped tubes, in the first of which the connector from the combustion tube opens; the upper portion of the first limb of the part A is charged with a plug of asbestos, *a*, and in the remainder, *b*, small pieces of hydrate of potassa are placed; fragments of glass occupy the bend, *c*, and the second limb, *d*, is filled with little lumps of caoutchouc. A tube, *e*, bent at right angles, and passing through perforated airtight corks, connects A with B, which is filled with dry sulphate of zinc, and which should be accurately weighed before the experiment. The asbestos in the portion *a* prevents solid particles from passing by the force of the vapor upon the potassa; the latter absorbs the carbonic acid and water, leaving the ammoniacal vapor and hydrocarbon gases to traverse further; the pieces of caoutchouc take up the combustible products, so that only the ammonia enters the tube B, where it is completely absorbed by the zinc salt. To insure accuracy in this operation, it is directed that the part A be immersed in water marking 170° before and after the experiment, so that any ammoniacal vapors contained in it may be driven over to B.

By weighing the tube B after the whole of the volatile alkali has been taken up, the increase of weight will show the quantity of ammonia produced, and from this the nitrogen is found, for seventeen parts by weight of the dry ammoniacal gas represent fourteen of nitrogen.

Having, by one or other of these processes, arrived at the knowledge of the quantity of carbon, hydrogen, and nitrogen contained in the fuel, the oxygen, if any, will be the difference between the combined weight of the three, and that of the entire organic or combustible matter. Sometimes, however, it is necessary to consider the sulphur in the analysis of coals, when this element is present in appreciable quantity; because, during the combustion of the substance in the air, it becomes oxidized, and passes off with the carbonic acid and water as sulphurous acid. Its quantity may

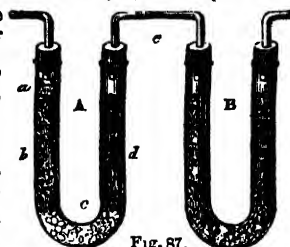


Fig. 87.

be determined by deflagrating a known weight of the coal with about two parts of nitre, and eight or ten of chloride of sodium, care being taken that both compounds be free from sulphuric acid; the sulphur is by this means oxidized into sulphuric acid, which becomes fixed by combining with the base of the nitre. By washing the mass with water, precipitating the acidified solution by chloride of barium, collecting the sulphate of baryta, and drying, burning, and weighing the latter, the quantity of sulphur may be calculated. About five-eighths of the portion of sulphur should be deducted from the oxygen or loss expressed in the foregoing, and the difference taken as the true value of the oxygen contained in the compound.

Although the ultimate analysis gives a comprehensive insight into the nature of a fuel, and likewise a means of finding its heating power theoretically; still it leaves much to be desired in practice to enable one to form a correct estimate of its actual heating effect in manufacturing operations. Many circumstances concur to render the amount of work which a given quantity of fuel will perform, less than theory indicates—the principal cause of the discrepancy being the want of such an arrangement of furnaces, as that the whole of the caloric should be directed to, and actually enter into, the performance of the work to be done. This is a desideratum which can scarcely be expected to be attained in so complete a manner as to yield practical results, agreeing exactly with calculations founded on the nature of the fuel; the closer, however, that one can approach to this standard the greater will be the economy realized, and the nearer will the practical results coincide with the deductions of theory.

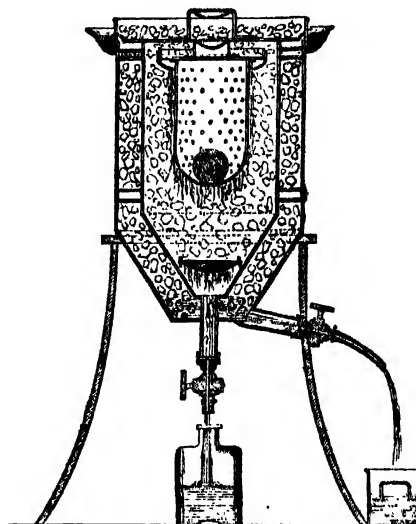
To arrive at an exact knowledge of the actual quantity of heat which a fuel ought to produce by combustion is impossible, no means being at hand for insuring definiteness to the result; but when, as in the determination of the atomic equivalent of a body, an arbitrary standard is taken, and the quantity of heat which other bodies produce is estimated with relation to such a standard, a comparative measurement is arrived at, which, though not expressing the absolute amount of heat produced, serves all the requirements of the arts. The arbitrary standard assumed, is the quantity of the fuel required to raise the temperature of a given weight of water a certain number of degrees, or the quantity of water which a given weight of the fuel or combustible will raise one degree. This amount, whatever it may be, is taken as the unit of heating power, and the number of such units, or the fractions thereof, which an equal weight of any particular fuel indicates by experiment, is taken as the heating or calorific power of that combustible.

ESTIMATION OF HEATING POWER.—Several investigators have bestowed considerable attention upon the subject of the quantity of caloric developed by the combustion of different substances. LAVOISIER, LAPLACE, and RUMFORD, were the first to enter this field, and the research has been prosecuted with increasing success by several others, down to the recent investigations of DESPRETZ, DULONG, and ANDREWS. The

principle upon which one and all founded their experiments, was that of determining the effect produced upon a third body by the heat given out during the union of the combustible under examination with oxygen.

In the experiments of LAVOISIER and LAPLACE, the body employed for this purpose was pounded ice, which was so applied around a balloon as to intercept all the heat. Fig. 88 shows a section of their apparatus, which they termed a *calorimeter*. The heating power

Fig. 88.



was estimated in this case from the quantity of water produced by the melting of the ice, and which flowed into the receivers, as seen in the engraving. These philosophers determined the amount of heat requisite to melt one pound of ice, as being sufficient to raise the same weight of water at 32° to 135° , or 103 pounds of water one degree. The more accurate experiments of BREVOSTAYE, DESAINS, REGNAULT, and others, as stated in a preceding part of this article—Vol. II., page 20—have shown that the heat which melts one pound of ice is sufficient to raise an equal weight of water to 142° , or seven degrees higher than was estimated by LAPLACE and LAVOISIER.

A moment's consideration of this method will convince the reader that it was liable to lead to wrong results, because it was impossible to recover the whole of the water produced by the liquefaction of the ice. This is the principal reason why the numbers given by these original investigators are too low. RUMFORD substituted water for the ice, the increase of the temperature of which, after the absorption of the caloric, as indicated by a delicate thermometer, was taken as the measure of the heating power of the substance tested. Many improvements have been made on RUMFORD's method, which is now generally followed in the prosecution of these inquiries. The heating value of any substance is estimated from the number of pounds or parts of a pound of water, which one pound weight of the substance to be tried will

raise one degree of Fahrenheit. The following table shows the results arrived at by different experimenters:—

Name of Combustible.	Symbol.	Symbol of product of combustion.	Pounds of water raised 1° by one pound of substance or unit of heat.	Pounds of water raised 1° when one pound of oxygen combines with the combustible.	Authorities.
Hydrogen,.....	H	HO	20,624	2,578	Despretz.
			23,640	2,955	Despretz.
			21,375	2,672	Lavoisier.
			24,000	3,000	Dalton.
			34,743	4,343	Dulong.
			34,792	4,349	Hess.
			36,000	4,500	Crawford.
			34,666	4,333	Grassi.
			34,662	4,333	Favre and Selbermann.
			33,808	4,226	Andrews.
			3,000	1,125	Dalton.
			5,175	1,911	Crawford.
Carbon,.....	C	CO ₂	5,325	1,997	Rumford.
			7,167	2,688	Dulong.
			7,237	2,714	Lavoisier.
			7,815	2,931	Despretz.
			7,912	2,967	Despretz.
			7,714	2,893	Grassi.
			7,500	2,962	Andrews.
			1,875	3,031	Dalton.
			2,634	4,609	Dulong.
			1,854	3,214	Grassi.
			2,431	4,254	Andrews.
			4,500	3,532	Dalton.
Phosphorus,.....	P	PO ₅	7,500	5,696	Lavoisier.
			5,747	4,509	Andrews.
			1,500	1,500	Dalton.
Sulphur,.....	S	SO ₂	2,571	2,571	Hess.
			2,601	2,601	Dulong.
			2,307	2,307	Andrews.
Antimony,.....	Sb	Sb O ₃	961	5,875	Dulong.
Zinc,.....	Zn	Zn O	1,314	5,290	Dulong.
Tin,.....	Sn	Sn O ₂	1,301	5,366	Andrews.
			1,283	4,545	Dulong.
Protoxide of tin,.....	Sn O	Sn O ₂	1,144	4,230	Andrews.
			534	4,473	Dulong.
			521	4,349	Andrews.
Iron,.....	Fe	Fe ₃ O ₄	1,702	4,340	Dulong.
			2,088	5,325	Despretz.
			1,578	4,134	Andrews.
Cobalt,.....	Co	Co O	1,080	3,995	Dulong.
Nickel,.....	Ni	Ni O	1,006	3,723	Dulong.
Copper,.....	Cu	Cu O	632	2,512	Dulong.
			602	2,394	Andrews.
Suboxide of copper,.....	Cu ₂ O	2 Cu O	244	2,185	Dulong.
Cyanogen,.....	C ₂ N	2 CO ₂ , N	256	2,288	Andrews.
			5,195	4,241	Dulong.
			6,375	1,594	Dalton.
Marsh gas,.....	C H ₄	CO ₂ , 2 H ₂ O	13,185	3,296	Dulong.
			11,098	2,774	Grassi.
			13,158	3,289	Favre and Selbermann.
			13,108	3,277	Andrews.
			6,600	1,925	Dalton.
Olefiant gas,.....	C H ₂	CO ₂ , H ₂ O	12,030	3,296	Dulong.
			8,436	2,461	Grassi.
			11,900	3,471	Favre and Selbermann.
			11,942	3,483	Andrews.
			4,350	2,084	Dalton.
Alcohol,.....	C ₄ H ₆ O ₂	4 CO ₂ , 6 H ₂ O	6,750	3,234	Rumford.
			6,909	3,311	Dulong.
			6,566	3,146	Grassi.
			7,183	3,442	Favre and Selbermann.
			6,850	3,282	Andrews.
Ether,.....	C ₄ H ₈ O	4 CO ₂ , 5 H ₂ O	4,650	1,792	Dalton.
			8,025	2,093	Rumford.
			9,431	3,634	Dulong.
			9,027	3,480	Favre and Selbermann.
			5,839	3,893	Grassi.
Wood spirit,.....	C ₂ H ₄ O ₂	2 CO ₂ , 4 H ₂ O	5,304	3,536	Favre and Selbermann.
Fousel oil,.....	C ₁₀ H ₁₂ O ₂	10 CO ₂ , 12 H ₂ O	8,959	3,285	Favre and Selbermann.
Amylic ether,.....	C ₁₀ H ₁₁ O	10 CO ₂ , 11 H ₂ O	10,188	3,353	Favre and Selbermann.
Acetone,.....	C ₃ H ₆ O	3 CO ₂ , 3 H ₂ O	7,320	3,317	Favre and Selbermann.
Rock oil,.....	C H	CO ₂ , H ₂ O	7,335	2,139	Rumford.
Oil of turpentine,.....	C ₅ H ₈	5 CO ₂ , 4 H ₂ O	4,500	1,339	Dalton.
			10,496	3,187	Grassi.
			10,874	3,301	Favre and Selbermann.
Oil of lemons,.....	C ₁₀ H ₈	10 CO ₂ , 8 H ₂ O	10,663	3,237	Favre and Selbermann.
Terebene,.....	C ₁₀ H ₈	10 CO ₂ , 8 H ₂ O	10,959	3,327	Favre and Selbermann.
Camphor,.....	C ₁₀ H ₈ O	10 CO ₂ , 8 H ₂ O	5,250	1,847	Dalton.

Name of Combustible.	Symbol.	Symbol of product of combustion.	Pounds of water raised 1° by one pound of substance or units of heat.	Pounds of water raised 1° when one pound of oxygen combines with the combustible.	Authorities.
Olive oil,	$C_{10}H_8O$	$10CO_2, 8H_2O$	6,675	—	Crawford.
			7,800	—	Dalton.
			9,045	—	Rumford.
			9,862	—	Dulong.
			11,100	—	Lavoisier.
			9,300	—	Rumford.
			7,800	—	Dalton.
			8,370	—	Rumford.
			7,273	—	Crawford.
			7,800	—	Dalton.
			9,472	—	Rumford.
			9,975	—	Lavoisier.
			2,105	—	Dalton.

The fifth column in the preceding table has been given, as having reference to a law propounded by WELTER, namely, that all combustible bodies disengage the same amount of heat during their combination with the same weight of oxygen; or, in other words, that the caloric developed was proportionate to the amount of oxygen assimilated during the combustion. WELTER founded this theory upon the results of LAPLACE, LAVOISIER, DESPRETZ, RUMFORD, and others, which must be admitted to be less trustworthy than those obtained by DULONG, GRASSI, ANDREWS, and other modern investigators; and it will be seen that when the numbers of the latter are adopted, the relation sought to be established does not hold good. To give one instance: hydrogen combines exactly with three times the quantity of oxygen that carbon takes up, and so from WELTER's theory the heat developed should be three times greater when hydrogen is burned, than when an equal weight of pure carbon is subjected to the same process; but from the results of the last-mentioned chemists, the ratio is between one to four and one to five. This wide difference is only observable, however, with combustibles very dissimilar in their nature, for when they approach to identity in physical appearance, as wood, peat, and coal, the estimation of the oxygen taken up gives an average indication of the heating power of the substance, which, without being absolutely correct, will answer most purposes.

BERTHIER has founded a system of analysis upon this theory, by which the oxygen is estimated, and therefrom the heating power of the fuel deduced. It is easy and expeditious, and may, under the foregoing circumstances, be occasionally adopted. He mixes a weighed portion of the finely-powdered fuel with thirty to forty times its weight of oxide of lead—litharge—and introduces the compound into a fireclay crucible, pressing it gently, and covering the whole with a thick layer of the litharge. The crucible is then carefully closed, and placed on the fire, where it is gently heated till the whole of the carbon and hydrogen is burned. During this process, the mass, being semifluid, is considerably distended by the carbonic acid and water, resulting from the combination of the elements of the fuel with the oxygen of the metallic oxide; towards the end of the operation, therefore, the fire should be quickened, and as soon as the crucible has attained a bright redness, it should be taken out, and its bottom struck gently against a stone or piece of iron, so as to cause the particles of reduced metal to accumulate and form a button. As soon as cold the crucible is broken,

and the metal, coated with oxide of lead and slags from the ashes of the fuel, is abstracted. It is cleaned from the adhering impurities by a few blows of a hammer upon the anvil, and subsequent brushing, after which it is weighed. From the number thus found, the oxygen required for the combustion of the fuel is calculated, since it is derived from the oxide of lead—a definite compound of equivalent proportions of lead and oxygen. When pure carbon is operated upon in this way, it has been found that about thirty-four and a half times the weight of the sample of metallic lead has been obtained. This amount of metal stands in a definite relation to the oxygen entering into the combustion, and, consequently, according to the law propounded, to the heating power of the fuel also; for, supposing a certain weight of metal to be produced, the following ratio will give the heating power of the fuel: namely, as the metal obtained when operating with pure charcoal is to that reduced by the substance under experiment, so is the number expressing the units of heat of carbon to that of the fuel. For instance, the weight of metal obtained with pure charcoal is 34.5; allowing that with the subject of the experiment to be twenty; and taking ANDREWS' determination, or seven thousand nine hundred, to represent the heating power of the charcoal, while x represents the unknown heating power of the fuel; then,—

$$34.5 : 20 :: 7900 : x.$$

$$\text{Or, the heating power } x = \frac{20 \times 7900}{34.5} = 4580$$

nearly. If in a substance of a complex nature, such as wood, peat, coal, *et cetera*, the hydrogen and oxygen are in such a ratio as to form water by their combination, it is evident that the average result of the lead assay will approximate to the truth; but where this is not the case, and a quantity of hydrogen is present without oxygen to combine with it, the accuracy of the experiment is less to be depended on, because the heating equivalent of the former element is taken as if it were carbon, whereas it is shown by the foregoing table to be much higher. When great exactness is required, it is evident that the heating power must be determined from the elementary analysis of the substance and the estimated calorific power of the constituents. This may be done with considerable accuracy, since it does not alter the amount of heat developed, whether the combustion be effected under the influence of a concentrated stream of oxygen gas, or in ordinary

air. The method of performing the calculation is very simple. Supposing the elementary composition of the fuel examined to be as follows:—

	Per cent.
Carbon,	86.48
Hydrogen,	3.04
Oxygen,	7.10
Ashes,	3.38
	100.00

it would be necessary to deduct from these numbers the oxygen, and the equivalent of hydrogen which combines with it, and to account as available for raising the temperature only the remaining hydrogen and carbon. In the above analysis the equivalent of hydrogen which will unite with the oxygen of the substance, will

be $\frac{7.10}{8} = 0.8875$, which, when deducted from 3.04,

leaves 2.1525 as the weight of hydrogen which goes to generate heat. According to ANDREWS' numbers in the foregoing table, the units of heat which this

would produce may be expressed thus: $\frac{2.1525}{100} \times 33808 = 727.7$, and in like manner the carbon may be valued, $\frac{86.48}{100} \times 7900 = 6831.9$; making together

$727.7 + 6831.9 = 7559.6$ as the heating power of the fuel. In the same way may the value of any other kind of fuel be found.

Having the expression of the units of heat generated, it is easy to find the thermometric temperature which it produces; to do this, however, involves the necessity of knowing the quantity of air required for consuming the matter, and likewise the specific heat of the products. It is well known that air is composed of seventy-seven parts of nitrogen and twenty-three of oxygen, of which constituents only the latter is available in combustion. Having a knowledge of the proportionate quantity of oxygen required to burn the combustible elements, the volume of air containing this proportion may be readily found. Thus, every part of carbon combines with 2.66 of oxygen, which is yielded by 11.59 of atmospheric air; upon similar grounds, the air required for the combustion of hydrogen is 34.78 parts. In both cases, the products are carbonic acid, water, and nitrogen, the weight of which may be ascertained from the data given. Now the heat produced by the combinations of these distributes itself among the gases, so that they all indicate the same temperature, and which can be estimated, since the specific heat of these bodies is known. The number thus obtained, and which represents the temperature of combustion, varies, however, with the nature of the fuel; and still, owing, perhaps, to the specific heat of the gases at a high temperature, the results should be viewed only as an approximation.

As an example of the calculation of the pyrometrical heating power of a fuel, that already submitted may be again taken. It has been shown that the absolute heating effect of this specimen is 7559.6 units of heat, and that 0.8875 of the hydrogen contained in it is taken up by the oxygen, leaving 2.1525 of that element to undergo combustion with extraneous oxygen. It has been likewise stated that 11.59 parts of atmo-

spheric air are required for the complete combustion of one of carbon, and, upon the same grounds, that hydrogen requires 34.78; hence the weight of air required to convert the carbon and hydrogen of the fuel into carbonic acid and water would be—

$11.59 \times 86.48 = 1002.3$ parts for the carbon, and
 $34.78 \times 2.1525 = 74.8$ „ hydrogen;

making a total of 1077.1.

From these } 326.5 parts of carbonic acid,
 are produced }

19.37 „ water, and
 819.88 „ nitrogen, to which it
 is necessary to } 8.00 „ water, formed by the
 add }

union of the oxygen of the fuel with a portion of its hydrogen; thus making a total of $27.37 = 19.37 + 8.0$ parts of water. The specific heat of carbonic acid being 0.221, the amount of caloric required to raise 326.5 parts 1° would be $326.5 \times 0.221 = 62.16^\circ$. The specific heat of aqueous vapor is 0.847; hence, } $27.37 \times 0.847 = 23.18^\circ$
 the coefficient for nitro- } $819.88 \times 0.273 = 223.80^\circ$
 gen is 0.273; therefore, }

309.14

This number expresses the total amount of heat carried off by the products of the combustion of one hundred parts of the fuel; hence,

$$7559.6 \div \frac{309.14}{100} \text{ or } \frac{7559.6 \times 100}{309.14} = 2445.3;$$

which number represents the thermometrical heating effect of one part. In this calculation the specific heat of the ash has not been taken into account; but the quantity of caloric lost in this way is so insignificant, that the results are but very slightly affected by it.

Pursuing the same course, the pyrometrical heating effect of any other kind of fuel or combustible, however numerous its ingredients, may be ascertained; that is, by finding the absolute heating power by the formula already given for the purpose, and dividing it by the sum of the specific heat of the products multiplied by their total weight, the quotient will be the available heat for any particular work when the fuel is burned.

It may here be remarked, that when a fuel is consumed in oxygen gas, the pyrometrical effect is much greater than when the combustion takes place in ordinary air, although the units of heat are the same in both cases. The difference of effect arises from the fact, that the nitrogen of the air passing through the fire in considerable quantities, renders latent a large amount of heat—the difference between the indication in oxygen and air.

The following table shows the heating effect of a few combustibles, as well when burned in oxygen gas as in air, calculated according to the above formula:—

Pyrometrical Heating Power.			
Name.	Symbol.	In Oxygen.	In Atmospheric Air.
Carbon,	C.	9753°	2450°
Carbide of hydrogen,	C. H.	4944	2286
Ether,	C ₄ H ₈ O	4035	2070
Light carbide of hydrogen,	C. H ₂	4703	2273
Alcohol,	C ₄ H ₈ O	3407	1870
Hydrogen,	H	3491	2248

	Heating Effect.		
	Absolute	Specific	Pyrometric.
WOOD.			
Air-dried wood, with twenty per cent. of hygroscopic moisture,	0.36	—	1575
Kiln-dried " ten "	0.41	—	1675
Kiln-dried wood, without hygroscopic moisture,	0.47	—	1750
White beech, air-dried,	—	0.28	—
Oak,	—	0.26	—
Oak,	—	0.25	—
Ash,	—	0.24	—
Maple, birch, bird-cherry,	—	0.23	—
Red beech, horse chestnut, elm, white-thorn,	—	0.21	—
Scotch fir, alder,	—	0.20	—
Sallow,	—	0.19	—
Willow,	—	0.18	—
Spruce fir, silver fir, larch,	—	0.17	—
Lime, aspen,	—	0.16	—
Black poplar, Italian poplar,	—	0.14	—
TURF-PEAT.			
Imperfectly air-dried turf, with thirty per cent. of hygroscopic moisture and ten per cent. of ash,	0.37	—	1575
Best air-dried turf, with twenty-five per cent. of moisture and no ash,	0.47	—	1750
Kiln-dried turf, with no moisture and fifteen per cent. of ash,	0.55	—	1975
Best kiln-dried turf, without moisture and ash,	0.65	—	2000
LIGNITE.—BROWN COAL.			
Air-dried fibrous lignite, with twenty per cent. moisture and no ash,	0.48	0.55	1800
" " " " and ten per cent. of ash, ...	0.43	—	—
" earthy " " and no ash,	0.61	0.79	1975
" " " " and ten per cent. of ash,	0.55	—	—
Air-dried lignite, conchoidal fracture, with twenty per cent. moisture and no ash, ...	0.69	0.83	2050
" " " " and ten per cent. ash,	0.62	—	—
Kiln-dried fibrous lignite, with twenty per cent. moisture and no ash,	0.61	—	2025
The same, with twenty per cent. of moisture and ten per cent. of ash,	0.55	—	—
Kiln-dried earthy lignite, with twenty per cent. of moisture and no ash,	0.76	—	2125
The same, with twenty per cent. of moisture and ten per cent. of ash,	0.69	—	—
Kiln-dried conchoidal lignite, with twenty per cent. moisture and no ash,	0.85	—	2200
The same, with twenty per cent. of moisture and ten per cent. of ash,	0.76	—	—

COAL.	Heating Effect.		
	Absolute.	Specific.	Pyrometrical.
Sand coal, ..	0.79	1.06	2200
Sinter,	0.89	1.16	2250
Caking,	0.93	1.17	2300
Anthracite, ..	0.96	1.44	2350
with five per cent. of moisture and five per cent. of ash,			
WOOD CHARCOAL.			
Air-dried black charcoal, with twelve per cent. of moisture and three per cent. of ash,	0.97	—	2450
Perfectly dried black charcoal, with three per cent. of ash,	0.84	—	2350
Air dried red charcoal, with ten per cent. moisture and one and a-half per cent. ash, ..	0.72	—	2200
Perfectly dry red charcoal,	0.64	—	2100
Birch,	—	0.20	—
Ash, wild service,	—	0.19	—
Red beech, white beech, elm,	—	0.18	—
Red fir,	—	0.17	—
Maple,	—	0.16	—
Oak, pear tree,	—	0.15	—
Alder,	—	0.13	—
Lime,	—	0.10	—
no moisture, and three per cent. of ash,			
PEAT CHARCOAL.			
Worst description of air-dried peat charcoal, with ten per cent. moisture and fifty-six per cent. ash,	0.85	—	2050
Best air-dried peat charcoal, with ten per cent. moisture and four per cent. ash,	0.83	—	2350
COKE.			
Good coke, with ten per cent. moisture and five per cent. ash,	0.84	—	2350
Best " five " three per cent. ash,	0.92	—	2400
Ditto, with no moisture and three per cent. ash,	0.97	—	2450
Sand coal coke,	—	0.46	—
Sinter coal " } no moisture and five per cent. of ash,	—	0.41	—
Caking " " }	—	0.33	—
GASEOUS COMBUSTIBLES.—FURNACE GASES.			
Gases from wood charcoal, A,	0.108	0.000140	1675
" " B,	0.080	0.000104	1450
Gases from coke,	0.107	0.000139	1750
" " coal,	0.205	0.000267	1850
GENERATOR GASES.			
Gases from wood charcoal,	0.115	0.000150	1775
Gas from wood, I,	0.136	0.000177	1850
" " II,	0.124	0.000161	1575
Gas from turf,	0.092	0.000120	1525
Gas from coke,	0.110	0.000143	1775

It is assumed that the whole of the combustibles named in this table are consumed, but in practice this never happens; hence, the heating effects given are higher than would be found to result when performing actual service; further, it is taken for granted that the combustion takes place in the shortest possible period of time, and that whilst it lasts, an equal amount of caloric is evolved each instant, a condition never fulfilled in the furnace. The discrepancy produced by both these sources of error, between the practical results and theoretical calculations, is to some extent

counteracted by the high temperature required to commence the combustion.

Having alluded to the process published by BERTHER for the determination of the heating power of a fuel, the following tables are submitted as the results of his investigation; and although it will appear from what has been said in reference to WELTER's theory, that these results, from being founded upon it, are not quite correct, yet they may be useful as a close approximation to the pyrometric values of the substances mentioned:—

1.—WOOD.

Species of Wood	Dried in the ordinary manner Berthier		Containing nine per cent of water. Winkler.		Perfectly dried Schodler and Peterson			
	Pounds of fuel dried by one pound of wood.	Pounds of water which one pound can heat from 32° to 212°	Pounds of fuel reduced by one pound of wood	Pounds of water heated from 32° to 212° by one pound of wood	Pounds of oxygen required for the complete combustion of one pound of wood.	Pounds of water heated from 32° to 212° by one pound.	Air at 60° Fahr. required to consume one pound of wood.	
							In pounds. Hessian.	In C. F.
Oak,	12.5	28.3	14.05	31.82	1.358	39.82	5.83	151.4
Ash,	—	—	14.96	33.89	1.356	39.76	5.82	151.2
Sycamore,	13.1	29.7	14.16	32.07	1.391	40.85	5.98	148.4
Beech,	13.7	31.0	14.00	31.71	1.346	39.44	5.78	152.9
Birch,	14.0	31.7	14.08	31.90	1.356	39.73	5.82	153.0
Elm,	—	—	14.50	32.84	1.418	41.55	6.08	161.1
Poplar,	—	—	13.04	29.54	1.390	40.72	5.96	157.9
Lime-tree,	—	—	14.48	32.80	1.429	41.87	6.13	162.3
Willow,	—	—	13.10	29.67	1.352	39.61	5.80	153.6
Fir,	14.5	32.8	13.86	31.39	1.408	41.25	6.04	160.0
Pine,	13.7	31.0	13.88	31.44	1.392	40.82	5.98	158.2
Scotch fir,	—	—	13.27	30.06	1.393	40.85	5.98	158.3
Hornbeam,	12.5	28.3	—	—	—	—	—	—
Alder,	13.7	31.0	—	—	—	—	—	—
Larch,	—	—	—	—	1.408	41.25	6.04	160.0

II.—CHARCOAL.

Species of Charcoal.	Berthier.		Winkler.		Air required for perfect combustion.
	Pounds of lead reduced by one pound of charcoal.	Pounds of water heated from 32° to 212° by one pound of charcoal.	Pounds of lead reduced by one pound of charcoal.	Pounds of water heated from 32° to 212° by one pound of charcoal.	
Commercial.	Poplar charcoal.....	30.60	On an average 68	33.50	On an average of 293.5 C. F. Air at 66° Fahr.
	Sycamore ".....	30.60		33.23	
	Ash.....	29.60		33.23	
	Aspen.....	29.50		—	
Enclosed in bottles immediately after being made.	Fir.....	32.30	On an average 72	33.51	
	Alder.....	32.40		—	
	Birch.....	31.40		33.71	
	Oak.....	31.30		33.74	
	Beech.....	—		33.57	
	Elm.....	—		33.26	
	Lime-tree.....	—		32.79	
	Willow.....	—		33.49	
	Pine.....	—		33.53	
	Scotch fir.....	—		33.62	

III.—PEAT.

Source of Peat	Pounds of lead reduced by one pound of peat.	Pounds of water heated from 32° to 212° by one pound of peat.	
Peat from Troyes.....	8.0	18.1	Berthier.
" Ham, dép. de la Somme.....	12.3	27.9	
" Passy, dép. de la Marne.....	13.0	29.2	
" Framont, dép. de la Vosges.....	15.4	34.9	
" Ischoux, dép. Landes.....	15.3	31.6	
" Königsbrunn, Wittenberg.....	14.3	32.4	Winkler.
Among twenty-four sorts from Hartz } Mountain, the worst gave.....	11.9	26.9	
The best gave.....	18.8	42.6	
From Allen in Ireland.			
Upper peat.....	27.7	62.7	
Lower peat.....	25.0	56.6	Winkler.
Pressed peat.....	13.7	28.0	

IV.—PEAT CHARCOAL.

Source	Pounds of lead reduced by one pound of charcoal.	Pounds of water heated from 32° to 212° by one pound of charcoal.	
Crouy sur l'Oureq, depart. Seine et Marne.....	17.7	40.1	Berthier.
Seine et Ham.....	18.4	41.7	
Essone, much used in Paris.....	22.4	50.7	
Framont, and peat from Champ de Feu.....	26.0	58.9	

V.—BROWN COAL.

Locality.	Pounds of lead reduced by one pound of coal.	Pounds of water heated from 32° to 212° by one pound of coal.	
Gemende Dauphin, Basses Alpes.....	25.3	57.3	Berthier.
St. Martin de Vaud, Canton de Vaud.....	22.6	51.2	
Minerue, département de l'Ande.....	22.8	51.6	
Gardanne, Bouches du Rhône.....	22.0	49.8	
Fuvear.....	21.0	47.6	
Enfant Dort.....	21.0	47.6	
Koep Fuarch, lake of Zurich.....	20.7	46.9	
St. Lon, Basses Pyrenees.....	20.3	46.0	
Val. Pineau, dép. Sarthe.....	19.25	43.6	
Common German.....	18.40	41.7	
Edon, dép. de la Charente.....	17.0	38.5	Kuhnert.
Alpheus, Greece.....	16.3	36.9	
Triphitis, ".....	16.3	36.9	
Kum, ".....	15.8	38.8	
Elbogen, Bohemia.....	18.2	41.2	
Brown coal from Meissen.....	20.1	58.9	
Pitch coal ".....	15.9	46.6	
" Ringkuhl.....	16.9	49.5	
" Habichtswald.....	16.0	46.9	
Glance coal from Ringkuhl.....	19.3	56.5	
Pitch coal from Habichtswald.....	19.0	43.6	Berthier.
Lowest stratum, Ringkuhl.....	19.0	43.6	
Middle stratum.....	10.0	43.9	
Stillberger coal.....	14.1	41.3	
Lignite from Meissen.....	14.7	43.1	
" Laubach.....	17.5	51.3	Berthier.

Locality

Locality	Pounds of lead reduced by one pound of coal.	Pounds of water heated from 32° to 212° by one pound of coal.	
Earthy coal from Dax.....	21.38	62.6	Regnault, Varentrapp.
" " Bouches du Rhône.....	18.89	55.3	
" " Lower Alps.....	16.69	48.9	
" " Greece.....	17.84	52.3	
" " Cologne.....	18.24	53.4	
" " Usnach.....	15.90	46.6	Regnault, Varentrapp.
Helmstadt, Prinz Wilhelm's mine.....	20.17	59.1	
" other mines.....	21.83	63.9	
Schöningen, Gr. Irene.....	18.76	54.9	
" other mines.....	18.60	54.5	Berthier.

VI.—MINERAL COAL.

Locality and Species of Coal.	Pounds of lead reduced by one pound of coal.	Pounds of water heated from 32° to 212° by one pound of coal.
CAKING COAL.		
Coal from Dowlais, Wales,	31.8	72.0
Glamorgan,	31.2	70.7
Eschwiller, near Aix-la-Chapelle,	31.0	70.2
Lippe-Schaumburg,	30.9	70.0
Newcastle,	30.9	70.0
Curmeau, near Alby,	30.1	68.2
Rive-de-Gier, Grand Croix,	29.6	67.0
Mons, Bouleau Fontaine Madame,	29.0	65.7
Canal coal, Wigan,	28.3	64.1
Mons, Grand-Guillet,	28.1	63.6
Rochebelle, near Alais,	27.6	62.5
Bonchamp, Haute Saône,	27.3	61.8
Bessèges, Aveyron,	27.0	61.1
St. Pierre la Cour, near Meyenne,	27.6	61.1
Epinal, Saône and Loire,	26.8	60.7
From Oviedo in Asturia,	26.1	59.1
Freul mine, near St. Etienne,	25.4	57.5
Bellestat, Aude—called jet,	24.4	55.2
Jet—locality unknown,	23.3	52.8

VII.—COKE.

Species of Coke.	Pounds of lead reduced by one pound of coke.	Pounds of water heated from 32° to 212° by one pound of coke.	
A la Garre, from coal of St. Etienne.....	28.5	65.6	Berthier.
From coal of Bessèges.....	28.4	64.3	
" Rive-de-Gier.....	26.0	58.9	
Gas coke from Paris.....	22.0	50.3	

VIII.—ANTHRACITE.

Locality.	Pounds of load reduced by one pound of anthracite.	Pounds of water heated from 32° to 212° by one pound of anthracite.	
Anthracite, from Lamure, near Gre- noble,.....	31.6	71.5	Berthier.
Anthracite from Pennsylvania,.....	30.5	69.1	
From Laval, { la Chaumière,.....	33.0	74.7	
{ la Baconière,.....	26.6	60.2	
“ Corbatière in Savoy,.....	26.7	60.5	

The numbers cited in some of the preceding tables, as indicating the heating power of many kinds of fuel, appear at first sight contradictory to the known results obtained with such materials in the furnace. Thus considerably more heat is produced, judging from the work performed, when hard woods are burned than with the softer varieties; but numbers stated in the tables assign the greater heating power to the softer woods. SCHÖDLER and PETERSEN account for this apparent inconsistency by the difference in the amount of hydrogen producing unequal intensity of combustion in the two cases. They show that whilst woody fibre contains oxygen and hydrogen in the proportion in which they unite in water—that is, in the ratio of eight to one—all woods have the hydrogen in greater or less excess of the oxygen, and this excess acting at the temperature of combustion upon the carbon of the substance, produces a quantity of hydrocarbon gases, which are rapidly consumed. The residuary charcoal becomes in this case more porous, and, therefore, presents a larger surface to the oxygen of the air; the consequence of which is, that it is much more speedily consumed than if it remained a dense compact body. Hard woods have less hydrogen than the soft ones, and this fact accounts for the difference in the amount of heat produced. The annexed table gives the excess in one thousand parts after the oxygen has been assimilated:—

	Excess of hydrogen.
Ash,.....	5.05
Oak-wood,.....	5.08
Beech-wood,.....	6.50
Willow,.....	7.00
Birch,.....	7.50
Scotch fir,.....	7.70
Poplar-wood,.....	8.20
Maple,.....	8.30
Pine-wood,.....	8.80
Deal,.....	9.50
Elm,.....	10.00
Lime-wood,.....	13.90

In the other tables above given, it will be seen that the highest place is assigned to lime-wood in point of heating power; but, in practical application, the oak produces a better result. The difference of the time required for the combustion of the two accounts for the inequality. In the case of lime-wood, a considerable quantity of its carbon is taken up by the large excess of hydrogen, and is given off in the shape of inflammable gas, which presents an extended surface to the oxygen, and is consequently speedily consumed; the residuary charcoal burns rapidly on account of its porous nature, arising from the evolution of the particles of hydrogen and carbon. Now, oak-wood not having so large a per centage of hydrogen to react upon its carbon, of course a greater weight of the latter remains, and this being denser than in the case of lime-wood, a

less surface is undergoing combustion in the fire, and a longer time will be occupied in its burning. It rarely happens that the arrangements for the application of caloric in the arts are of such a nature as to allow of the entire economization of the heat produced, more especially when it is developed intensely and in a short space of time; hence, when soft woods are employed as fuel, there is a considerable amount of heat lost, by which the working effect is lessened. On the contrary, with woods which burn slowly, the loss is not so great, since it is nearly wholly absorbed in proportion as it is developed by the combustion. The same remark applies to coals; and this is the reason why particular kinds are employed for steam-generating purposes, for glass and porcelain works, *et cetera*; but although there appears a very great difference arising from this cause, yet it does not follow that the pyrometric effect of the one is less than that of the other. If, for instance, two equal weights of oak-wood be consumed—one in the form of chips or shavings, and the other in a compact mass—it will be seen that the former will burn in a much shorter period than the latter, and that the practical heating effect produced by the one will be much less than by the other. It is evident that the pyrometric heat is the same in both, only that the evolution of caloric from the divided portion is so rapid as to cause the dissipation of a large part of it. Where a high temperature is necessary, it is evident that a fuel capable of giving off its caloric in a comparatively short space of time is required; and hence the preference given to soft wood, or finely cleft hard wood, in the glass furnace and porcelain kiln. The facility which minute division affords for rapidity of combustion has, however, its limit, which, when exceeded, instead of expediting, retards, and when carried to extremes, actually arrests combustion entirely, as may be observed with coal, coke, wood, and peat charcoal, when crushed to a powder. In this case the air has no access to the combustible except at the surface, so that the area of contact is very limited when compared to the bulk, and, consequently, ignition is arrested. When it happens that fuel in this minutely divided state is the only kind available, the combustion is assisted by piling blocks of limestone, sandstone, or other material upon the grate, and placing the fuel—such as sawdust, slack, breeze, *et cetera*—upon them, in which case the currents, ascending through the interstices, supply the requisite oxygen to the fuel. If the grate does not admit of this arrangement, the finely-divided combustible is converted into a valuable compact fuel by blending it with tar, pitch, or some such binding material, as described under Patent Fuels.

In consequence of the defective furnace arrangements in most manufacturing establishments, the quantity of heat absorbed and utilized bears, in general, no definite relation to the quantity produced, without taking into account the proportion of the fuel, which is either not at all, or only partially burned. The loss from these two causes alone has been estimated to be equivalent to the one-half of the coals consumed under the imperfect systems generally followed. Of late years considerable attention has been directed to discover some means whereby the cause of the first loss might be

removed by an improved construction of the furnaces or fire-places, with a view to their better retention of the heat, and marked benefits have arisen to many branches of trade, but more especially to those making extensive use of steam, from the various investigations instituted. Although the waste of caloric from both the causes mentioned—namely, the non-retention of the heat and the imperfect combustion of the material—is very great; yet a considerable waste of fuel is occasioned by other circumstances which attend ordinary combustion, and which require investigation as much as the others. To enter into a minute discussion of all these would be tedious; but a short examination of the principal ones will be necessary, to point out the sources of the difference between the calculated value of fuel in heating power, estimated from experiments controlled in such a way as is not possible when the materials are burned in the ordinary furnace or grate, and that which results in practical operation.

In the first place, it will be evident that the mere maintaining of a fuel in a state of combustion, whether in a grate or furnace, involves, and is dependent upon, a certain loss of caloric, as well latent as sensible, in the production and expansion of the gases resulting from the change, whereby they ascend from the substance and admit the fresh air to keep up the chemical action. It is well known that, under the provision made for burning fuel of any description, the air which is admitted must always be greater than the amount which theory assigns as sufficient, otherwise the combustion would be imperfect, and a heavy loss sustained. Admitting, however, that no more than is absolutely necessary passes through the fire, it will be seen, on reflection, that still a great amount of heat is rendered useless by the draught in the chimney. From the tables already given, it appears that for the complete combustion of one pound of dry wood an average of 5.94, or in whole numbers, six pounds weight of air at 32°—equal one hundred and forty-eight cubic feet—are required. Admitting that this volume of gaseous matter passes off from the fire to the chimney at a temperature of 300°, the whole heat lost will be $1620^{\circ} - (6 \times 270)$ —or as much as is equivalent to raise nine pounds from 32° to 212°, and, therefore, as would effect an equal increase of temperature in 2.4 pounds of water. SCHÖDLER and PETERSEN have shown that one pound of dry wood raises 40.6 pounds of water from 32° to 212°; hence the loss sustained, in consequence of the heat which is carried into the chimney, is $\frac{2.4}{40.6} = .06$, or six per cent. It seldom happens, however, that the temperature of the escaping gases is so low as that assumed in this instance; and where their heat is greater, of course, the loss will be proportionally increased; and the same effect will follow when the quantity of air passing through the furnace is greater than the theoretical amount.

Another cause of the reduction of the heat, and the prevention of a due effect resulting from combustion in the furnace, is the water which is usually present in fuels in greater or less abundance. The loss suffered from this alone is twofold: firstly, inasmuch as the amount of real combustible is diminished by it, whe-

ther it be large or small; and, secondly, because by its conversion into steam, in which state it passes off with the products of combustion, it unites with a large amount of caloric, which becomes latent.

When the proportion of water is appreciable, the quantity of caloric which is given off is very great. Wood, for instance, contains, after being dried in air, about one-fifth of its weight of moisture, so that when employed in this state as a fuel, only four-fifths of the weight taken is capable of generating heat. Supposing that 40.6 pounds of water are heated from 32° to 212° by one pound of wood perfectly free from moisture, it is evident that only 32.5 pounds would be brought to the same degree by the available fuel in the pound of common air-dried wood. Further, the one-fifth of moisture is expelled in steam, and this takes up as much caloric as would bring 5.5 pounds of water from the freezing to the boiling point. Founding a calculation upon this fact, the one-fifth of a pound of water present would assimilate as much heat as would raise 1.1 pound of water to the boiling point. By adding both, the total loss will be $9.2 - 8.1 + 1.1$ —or 22.5 per cent. less than if dry wood were employed. This example shows, in a striking manner, the great advantages which the employment of wood, peat, lignite, or such fuel as is liable to be more or less saturated with hygroscopic matter affords, when they are thoroughly exsiccated, over the same when containing ten, fifteen, or twenty per cent. of moisture. Where wood is much employed, care is taken to submit it to a preliminary drying operation, so that its combustion may be rapid, and that the loss described may be avoided.

It may be remarked, however, that water does not, under all circumstances, diminish the calorific effect of a fuel; but on the contrary, when judiciously managed, adds to it in a high degree. BUNSEN and FYFE have shown that aqueous vapor passed over incandescent fuel suffers decomposition; its oxygen is abstracted by the highly heated carbon, and carbonic oxide results, while the hydrogen passes off partly uncombined, and partly associated as carbide of hydrogen. These three products in the presence of sufficient oxygen, and the high temperature of the furnace, are capable of undergoing further combustion, and yield a large amount of heat by being converted into carbonic acid and water. In numerous experiments it was shown that the caloric developed in this manner, more than compensated for the fuel employed in producing the gases. The application of aqueous vapor, however, demands caution; for when used in too great an excess, it reduces, rather than increases the temperature of the fire. Its effect is to diminish the heat, unless used sparingly, and with a free admission of air to promote the combustion of the inflammable gases.

The method in which water is utilized for raising the temperature, is to place a vessel of this liquid beneath the bars, so that the heat radiated downwards may have the effect of producing the steam without further trouble; where steam-engines are employed, a jet of the waste vapor is allowed to issue under the furnace. A mistaken inference from this fact leads many to moisten the coals before throwing them on the fire,

with a view to the increase of the heat; but that the contrary effect is produced, is evident from what has been already detailed; the water in this case serves only to slacken the combustion, and render a considerable amount of heat latent. It is the practice, especially, to moisten small coals and slack; when it is required to burn them on the furnace bars, and in this case the loss in heat from the presence of the water may to a certain extent be compensated by the advantage of the adhesion produced between the particles of the fuel, whereby it is prevented from falling into the ash or stoke-hole. Clay, plaster, or bituminous substances would serve better.

Besides the loss of caloric which results from the gases or products of combustion passing in a superheated state into the chimney, as well as from the presence of an excess of moisture, there is another source of loss which is of far greater importance, and which is much more generally felt. It is necessary for keeping up the ignition that the column of air in the chimney be expanded by heat, and thus rendered specifically lighter than the surrounding atmosphere, to produce a constant current through the fire. The moisture in a fuel may be removed by a preliminary desiccation, the extent of the heat-absorbing surface may, under certain circumstances, be augmented, so as to arrest and economize a large amount of caloric which might otherwise be lost; but to effect a complete combustion of the fuel, with the least possible volume of air, demands a thorough knowledge of the scientific principles involved in this change, as well as of the products resulting therefrom, together with the strictest attention on the part of the *stoker*. It is evident that a definite relation must exist between the weight of combustible elements in a fuel, and the oxygen which is required to convert these into carbonic acid and water, and that to effect the latter change within the limits of this relation requires the most favorable circumstances, such as properly arranged furnaces, the adjustment of the fuel and draught of air passing through the fire, with skill and constant attention on the part of the fireman.

In a grate of any given dimensions, and burning a given weight of fuel in a determinate period, the quantity of air to be supplied can be easily deduced with the aid of known experimental results, as well as from theoretical calculations. Thus, according to the determinations and analyses quoted at page 112, one pound of peat requires for complete combustion from seventy to one hundred and thirty-four cubic feet of air at 66° 2'; medium kinds of this fuel, one hundred and forty-nine cubic feet; one pound of peat charcoal requires one hundred and fifty-five to two hundred and twenty-eight cubic feet; one pound of brown coal, according to the lead test, one hundred and thirty-nine to two hundred and twenty-two cubic feet, and by analysis, one hundred and sixty to two hundred and forty-eight; one pound of coal requires, by the lead test, one hundred and seventy to two hundred and seventy-nine, average qualities two hundred and twenty-eight cubic feet; according to RICHARDSON'S analysis, from two hundred and forty-eight to three hundred and three; by REGNAULT'S, average qualities, from the coal formation, take three hundred and twenty to three hundred and

thirty-two—those from the secondary formation, two hundred and ninety-three to three hundred and twenty-six cubic feet; one pound of coke requires one hundred and ninety-four to two hundred and fifty cubic feet; one pound of anthracite, according to the lead experiment, demands two hundred and thirty-three to two hundred and seventy-seven—according to REGNAULT'S analysis, three hundred and twelve cubic feet. A cubic foot of air weighs 0.03794 pound Hessian—0.07500 English—at the above temperature.—*Richardson and Ronalds*.

Now, in these calculations, it is presumed that the oxygen of the air is in contact with every particle of the fuel during ignition. Could the same condition be insured in the furnace, it is evident that the great desideratum required in combustion would be attained; no escape of combustible gas could then ensue, nor of the carbonaceous particles which give to the gases passing up the chimney the character of smoke; and the greatest possible heat arising from the burning of the substance in air would be developed. Indeed, nothing would be wanting to extract from the fuel the benefit of its total theoretical heating power, but such an arrangement of the furnace as would perfectly utilize the caloric so produced. No one, however, who has any experience as to the manner in which the fire is managed in the ordinary kinds of furnaces, will hesitate to assert that the above conditions are never supplied. The coals are thrown in thick layers upon the grate, by which the existing temperature for a time is greatly depressed, being absorbed in part by the cold fuel, and by the dispersion of its hygroscopic matter. In addition to the reduction of the heat temporarily, the thick bed of fuel impedes the draught, and sufficient air cannot enter to effect a consumption of coals, adequate to the generation of the amount of heat required. The portion of air which traverses the fire is deoxidized by the ignited fuel on the bars, and no oxygen, for a considerable period, can come into contact with the mass lying upon that which is burning; but although in this way it does not contribute to the pyrometrical effect, the temperature of the ignited mass, and the heated gases permeating it from below, cause a distillatory change, by which the whole of the available hydrogen, together with a large percentage of the carbon, is expelled as hydrocarbon gases, which escape combustion. This decomposition, occasioned by the undue fuelling, does not only waste the combustible matter in the way alluded to, but it diminishes the heat which is produced by the portion that burns, since the gases in passing off carry with them a considerable portion of caloric as latent and sensible heat. Further, after the distillation of the gaseous matter is effected, and the residuary coke has acquired incandescence, an additional loss is sustained in consequence of the carbonic acid in which the combustion of the carbon in the base of the fire terminates, being, by the deoxidizing power of the overlying glowing combustible, transformed into carbonic oxide, the abstracted oxygen taking as much again of the carbon as it would do if perfect combustion had occurred. The double volume of gas produced under these circumstances renders a large quantity of heat ineffectual for useful application.

It is thus that three radical and distinct sources of loss arise out of the profligate system of stoking usually practised; namely, waste of the volatile inflammable hydrocarbon gases of the substance; loss of the fixed carbon by the deoxidation of the carbonic acid; and, lastly, loss of the caloric with which the combustible and non-combustible gases combine and carry off, as well in the state of latent as of sensible heat.

Independently of such gross waste in the application of fuel, another of no little moment exists—namely, the rapidity of the draught in the flues. Experiments have shown that in those cases where the flue has been lengthened with the view of affording a greater heating surface, the effect produced was materially affected by having the damper entirely withdrawn, or only partially so. Such a result is a natural one, considering the imperfect conducting power of air, and also of water, when it is on the point of passing into the state of elastic vapor; for the one does not transmit the caloric to the fluid, nor does the latter combine with it so readily as to sufficiently abstract this principle from the gases when they rapidly circulate around the boiler and pass away. URE illustrates this non-conducting quality of gases passing rapidly over a conducting surface by the slight elevation of temperature which is experienced in guns, cannon, *et cetera*, notwithstanding that the temperature produced by the combustion of the powder is very high. The reason is, that the rapid evolution of the gases prevents the absorption of the caloric by the metal. In the case of a furnace, the barrel of the gun may be represented by the flue; the force of the explosion, and the products therefrom, by the draught and vapors produced in an ordinary furnace; and the effect of non-absorption in the latter instance, will be as marked as in the former if the draught be too great. Hence it will be readily inferred, that to absorb the whole or the greater part of caloric, time must form an important consideration to afford a more or less prolonged contact of the heated gases with the material of the boiler; consequently, where the draught is increased rather than checked within proper limits, the pyrometrical effect is, to a considerable extent, lost.

The causes of these losses in the production of heating effect, and, consequently, of mechanical power, have of late years engaged much attention, as well in America as in this country; and although the investigations, which have been conducted with a view to ascertain the conditions by which the largest amount of work might be performed by the fuel, have added materially to the knowledge of those circumstances that affect the heating power, they have scarcely touched upon those which relate to the economizing of fuel. Several modifications of furnaces have been patented of late years for the prevention of smoke, while, at the same time, it is alleged that the heat of the fire is increased; but it is to be feared that many of these arrangements, while ostensibly obviating one evil, produce others quite as injurious. This arises for the most part from the injudicious introduction of cold air at a part where the temperature is too low to cause combustion of the inflammable vapors and portions of carbon; or the quantity of air admitted is too great, and

the heat rendered latent by it amounts to as much or perhaps more than in the ordinary fire. Much benefit will doubtless accrue from those improvements in the furnace by which the supply of fuel upon the grate is regulated, and rendered more or less independent of the stoker. By these the loss arising from imperfect combustion, as already explained, is to a great degree avoided. To enter into a discussion and notice of the several improvements would be, in some degree, foreign to the subject of this article; but the reader who may be desirous of information on this matter, is referred to a work by Mr. W. WYE WILLIAMS, to the *Dictionnaire des Arts et de Manufactures*, published by LABOULAYE, and to KNAPP, RONALDS, and RICHARDSON on *Fuel*.

Regarding the investigations above alluded to, the chief object with which they were undertaken was to find the best coal for steam navigation. As already mentioned, there are many kinds of coal, which, though capable of producing a high temperature during combustion, yet are not economical for the purposes of the navy or other boiler furnaces. The reasons have been already stated. To find the best among the numerous varieties of coal extracted even from the same pits, and still more from different fields, the Government of the United States intrusted Professor W. R. JOHNSON with the investigation. This example was soon followed by Great Britain, whose manufacturing and naval interests, depending so much on steam, rendered such an inquiry most urgent. Dr. LYON PLAYFAIR and Sir HENRY DE LA BECHE were appointed as the principals in this research. In both the American and British investigations, the experiments were made with reference to the following principles:—

Firstly. The fuel should burn so that steam may be raised in a short period, if this be desired; in other words, it should be able to produce a quick action.

Secondly. It should possess high evaporating power—that is, be capable of converting much water into steam with a small consumption of coal.

Thirdly. It should not be bituminous, lest so much smoke be generated as to betray the position of vessels of war when it is desirable that this should be concealed.

Fourthly. It should possess considerable cohesion of its particles, so that it may not be broken into small fragments by the constant attrition which it may experience in the ship.

Fifthly. It should combine a considerable density with such mechanical structure that it may be easily stowed away into small space—a condition which, in coals of equal evaporative values, often involves a difference of more than twenty per cent.

Sixthly. It should be free from any considerable quantity of sulphur, and it should not progressively decay, both of which circumstances render it liable to spontaneous combustion.

The boiler employed by JOHNSON in his trials of the evaporating power of coals, was thirty feet long, and three and a half in diameter; this was set over a furnace, and the heated gases, after passing through two interior return flues, each one foot in diameter, escaped by the side flues exterior to the boiler to the chimney, making the entire length of circuit for

the products of combustion one hundred and twenty-one feet. The grate surface was sixteen feet and a quarter, and the area of heat-absorbing surface three hundred and seventy-seven and a half square feet, so that the ratio of both surfaces was as one to 23·2. The chimney was sixty-three feet high, and had a cross section of three hundred and twenty-four square inches.

On the other hand, a Cornish boiler was employed in the English investigation, the length of which was twelve feet, with an external diameter of four feet. The furnace, as usual with this class of steam boilers, was constructed in a flue two feet in diameter passing through the middle of the vessel. After the products of combustion traversed the central flue, they returned by two other external side ones to the front, and thence entered a main under the boiler, and which led to the chimney, thus making a course of thirty-six feet. A grate five feet square was employed, and the absorbing surface amounted to 197·6 square feet, so that the latter was to that of the fire as 1 to 39·5. In this case the height of the chimney was 35·5 feet, and its cross section presented an area of 182·25 square inches.

The amount of coals consumed in the hundred and forty-four trials made by JOHNSON at Washington was sixty-two and a half tons; and, in the eighty-two experiments conducted at London by PLAYFAIR and DE LA BECHE, about fourteen tons six hundred. The average weight of coals burned in the American inquiry at once was eight hundred two quarters twenty-six pounds, and in the English, three hundred two quarters.

The results of these experiments were published by Professor JOHNSON in a Report to Congress in 1844, and by Sir HENRY DE LA BECHE and DR. LYON

PLAYFAIR in a series of Reports to the British Government, concluded in 1851; but the relation between the composition of the coal, as ascertained by analysis, and its value for producing steam, is not by any means very clearly brought out even by these experiments. They prove, indeed, by the very differences which they exhibit, as compared with the results of experience, that the only trustworthy method of determining the value of a fuel, especially for steam purposes, is that of practical experiment under the boiler, where several tons and not pounds are consumed. It appears, therefore, to be unnecessary to transcribe the voluminous and elaborate tables embraced in the American and English reports, which the few readers who may be desirous to inspect them will find in RONALDS and RICHARDSON'S *Chemical Technology*. It may be stated, however, that in JOHNSON'S experiments the weight of water evaporated at 212° from one cubic foot of coal was found to vary from 440·8 to 556·1 pounds with different specimens of anthracite; from 350·2 to 478·7, with bituminous coking coal; and from 353·8 with Scotch, to 439·6 with English bituminous coal. In the English experiments, the Newcastle coal varies from 325·24 to 529·34; and Scotch coals from 352·58 to 460·82. The following may be given as a summary of the latter series of experiments, where A represents the evaporating power, or number of pounds of water evaporated at and above 212° by one pound of coal; B, rate of evaporation, or number of pounds evaporated per hour; C, weight in pounds of one cubic foot of coal, as used for fuel; D, space occupied by one ton in cubic feet; E, results obtained in experiments on cohesive power of coals, or, in other words, the per centage of large coals; and F, the per centage amount of sulphur contained in the coals:—

	A.	B.	C.	D.	E.	F.
Average of thirty-seven samples from Wales.....	9·05	448·2	53·1	42·71	60·9	1·42
“ seventeen samples from Newcastle,	8·37	411·1	49·8	45·3	67·5	0·94
“ twenty-eight samples from Lancashire, ..	7·94	447·6	49·7	45·15	73·5	1·42
“ eight samples from Scotland,	7·70	431·4	50·0	49·99	73·4	1·45
“ eight samples from Derbyshire,	7·58	432·7	47·2	47·15	80·9	1·01

The volume of the coals with reference to their respective qualities as a solid compact fuel was tested by JOHNSON, in the state in which they come to market, but in the English inquiry the several varieties were broken up into fragments not exceeding one pound in weight; hence the results in the latter were necessarily more uniform than in the former, and, therefore, the quantity of steam raised by equal bulks of the coal would from this, if from no other circumstance, be in favor of the English coals. Where the specific bulk of a fuel becomes a matter of consideration, as it must do when required for shipping, attention should be devoted to the size of the lumps, for even with the same coal there is great difference in the weights of two given volumes, one of which is in large and the other in smaller pieces.

The moisture present in the British coals was not deducted in calculating their evaporative value, as it was considered of greater practical importance to esti-

mate this in the state in which they were found in the market.

The British commission, besides employing the direct practical method—that of burning a portion of the coal under the boiler—had recourse for the calculation of the value of the fuel to the lead test, as also to the ultimate analysis. Between the results of these three methods there is often to be found in their tables a considerable difference, amounting even to a virtual contradiction. This has been shown to arise from the almost utter impossibility of economizing the heat under the boiler in the practical test, and from the fact of the oxygen derived from the litharge being made the basis for calculating the pyrometrical effect of the fuel in the lead test, an assumption that has been shown to be erroneous.

It is at least certain that very different quantities of steam were found to be raised by coals capable of reducing the same amount of lead, and hence it is evi-

dent that the lead test cannot be relied on as an exact measure of the value of a fuel, although it may afford an approximation. The same observation applies to the method of testing by the estimation of the coke or fixed carbon, the amount of which does not present a sure guide in the determination of the value of coal, since a wide difference was found between the steam generated or work done by different coals possessing an equal average amount of carbon.

With respect to the value which ought to be attached to the experimental results obtained by actually burning a portion of coals under the boiler, the information which even this method affords for practical guidance is not so reliable as might appear at first sight. This arises from the circumstance, that the effect of the fire depends to a great extent on the form and setting of the boiler; and as marine boilers differ from the Cornish ones in these particulars, the numbers found in the course of the experimental investigation do not present the actual equivalent of work to be expected in steamships. Even from the smallness of the boiler employed in the experiments, the results fell short by twenty per cent. of the maximum amount of work which the same fuels could perform when applied to larger boilers constructed and set on the same principles. The inquiry is rendered less efficient from another cause, namely, the want of a thorough control and measurement of the air passing through the furnace; for, doubtless, a knowledge of this would be of immense service in the application of fuel, so as to develop its entire pyrometrical effect under the most favorable circumstances.

The Editor concludes this article by acknowledging his obligations for much assistance to the very able work of RICHARDSON and RONALDS already referred to, as likewise to MILLER'S *Chemistry*, DUMAS' *Traité de Chimie Appliquée aux Arts*, and Dr. URE'S *Dictionary*.

GAS.—*Gas*, French; *Gaz*, German.—A recent writer appositely remarks, that in the present era, when the creative faculty of man seems to be more than ever busy in its obedience to the primitive injunction to subdue the earth, it seems but to be consistent with the harmony and order of the world that the production of light should have been one of the earliest aims of British industry. For the daily experience of social as well as of organic life, declares light to be one of the chief necessities of man, no less than of every other living thing; and sense and science alike at once accept as truth, that light was the first material force that worked in the embryo universe.

From the tallow dips of the last generation, powerless and void of everything save smell, to the bright stearic acid that cheers the drawing-room now-a-days, what a development! In the iron arteries under towns, in the constellations of burners that rule the nights of favored days, rising over the chaotic oil-lamps of old, what a creation! And can any one doubt that the same voice which first bade light to be, has summoned gas to the service of man, and pronounced the light from it to be good?

The discovery and earliest observation of elastic æriform fluids, capable of being inflamed and of imparting light and heat, must, according to HUGHES,

undoubtedly have been of great antiquity. The most ancient writings contain notices of inflammable vapors springing from fissures and cavities in the earth. It is evident, therefore, that gas being a natural production, no such individual as the discoverer and inventor of gas ever existed. Modern chemistry will have no difficulty in showing that all inflammable gases, whether arising naturally from rocks, or produced artificially by combustion or otherwise, are composed of simple elements, which present a remarkable analogy to the common bihydride of carbon, the gas chiefly consumed in our street lamps and houses at the present day.

Inflammable gas may be truly said to be as old as the first creation of organic matter, for wherever animal or vegetal substances have existed, by the immutable laws of nature they have been subject to cremacausis, and wherever decomposition has taken place, a variety of gases has been produced, some of them combustible, and others not. Whether the change be that engendered by the slow combustion of decay, or that more speedy process caused by the application of sensible heat, the effect is the same—the gases are equally produced in the two cases.

Gas may, in one sense, be called a more natural production than steam, although the latter has existed from the first creation of water, and in its palpable state, as proceeding from boiling water, must have been observed in all ages.

The *discoveries* of man in respect to gas and steam, ought rather to be called *applications*; they are conquests over the elements, the subjugation of great powers in nature to his use and convenience. So it is with nearly all great inventions, in which is found one power of nature after another, chained, confined, bound down, stored, and then let loose when required, and made to work machines, to propel ships across the ocean, to supply the place of human exertion itself in a thousand different ways; nay, to pass far beyond the actual powers of the combined labor of multitudes, and to effect that by a single effort which the manual strength of a world could scarcely accomplish.

If such astonishing applications of steam and gas had been made in the days of ancient Greece, what magnificent, expressive, and high-sounding names would have been found to convey their meaning! Instead of such contemptible little monosyllables as *gas* and *steam*, one might have heard of the spirit of coal and the spirit of water, with some superlative adjective to stamp the vast importance of each. In such an age these wonderful conquests would have thrown all meaner efforts into the shade; for them alone would poetry have strung its harp, and the grandest epic productions of genius might have commemorated the victory of man over the inanimate matter of nature, instead of dedicating her loftiest songs to the art of war.

As already stated, jets of flaming gases bursting out from the ground have attracted notice from a very early date, so that savage tribes, owing to the grandeur of the spectacle, apparently unsupported by fuel, considered the spots whence such emanated as the abodes of their gods. The well-known holy fires of Baku still burn, and are due to the ignition of light carbide of hydrogen with some naphtha vapor. They

are worshipped by the savages in the neighborhood of the Caspian Sea. In China, the borers for salt water often meet with streams of combustible gases, which they employ for illuminating factories and evaporating brines; consequently, the Chinese were acquainted with the use of coal-gas, long before the knowledge of its application was acquired by Europeans. The most familiar instance of the elimination of inflammable gases from the earth in this country, is the fire-damp of the miners; but it is not of such a good quality as that artificially produced.

Some of the earlier nations considered fire as a type of divinity, and one can scarcely wonder at the feelings of veneration occasioned by mysterious outbursts of flame, the origin of which appeared utterly incomprehensible. Hence superstition erected her altars over such flames, and claimed the interference of the gods to sustain the perpetual miracle. But all that had been observed with reference to inflammable vapors in olden times, was very far indeed from leading to any attempt to collect and use them. Their very nature and composition were unknown, and the most mistaken ideas prevailed as to their real elements. It was not until modern chemistry had exploded volumes of ancient dogmas, had traced the so-called elements to far simpler forms, and had taught the laws according to which simple bodies are combined in order to constitute all forms of matter—it was not till then that it began to be seen that the inflammable vapor of coal, wood, oils, and other fatty substances, was analogous with the marsh gas which arises in bubbles from the decomposition of vegetables under water; that it was of the same nature as the *ignis fatuus* or *Will-o'-the-wisp*, which on the wild moor or bog has lighted many a traveller to destruction; finally, that it was nearly the same as the gas which arises from the decomposition of water, however effected; and that, in fact, one of the constituents of water, the greatest antagonist and extinguisher of flame, was itself the most inflammable substance in nature, namely, hydrogen gas; while oxygen, the other element, is the greatest supporter of combustion.

Various opinions have been hazarded to account for the almost perpetual fires which were kept burning on the ancient altars. These are mentioned by STRABO and PLUTARCH, who add that when they happened to be extinguished, they were lighted by invisible means. The altar in the temple of Ægina may be mentioned as affording a good explanation of the mystery. Here a round hole, about thirteen inches in diameter, is observed in a block of stone. The circular orifice opens into a square one, which passes down through solid stone to a depth of several feet. The lower extremity of the square hole communicates with a cavity in which Mr. DODWELL supposes a fire to have been constantly kept burning, so that the flame did not appear above the surface of the fissure. He says, nothing more would be necessary than to pour oil into the orifice, when the flames would immediately burst forth, and appear to have a miraculous origin.—*Hughes*.

Although the application of the gases produced by the destructive distillation of pit-coal, as a means of obtaining artificial light, appertains to modern times, yet the germ of it may be traced back nearly two cen-

turies. In the year 1659, THOMAS SHIRLEY is said to have attributed the exhalations from the burning well of Wigan, in Lancashire, to the subjacent coal beds; and in 1664, the observation was made by Dr. CLAYTON, that combustible illuminating gas was formed during the decomposition of coal by heat, and that this could be collected.

One hundred years afterwards application was made of the fact, but by mere accident. In 1787, Lord DUNDONALD, of Culross Abbey, in Scotland, took out a patent for making coal-tar, and erected near the Abbey a series of ovens for this purpose. The tar was conducted by pipes from the condensers into cylinders of brickwork, each of which had a small opening at the top for the escape of the incondensable part of the products. To these openings the workmen were in the habit of attaching a cast-iron pipe by means of a mass of soft clay, and lighting the gas at the other end to give them light during the darkness. His lordship, also, was in the habit of burning the gas in the Abbey as a curiosity; and, for this purpose, he had a vessel constructed resembling a large tea-urn, which he frequently caused to be filled and carried up to the Abbey to light the hall with, especially when he had company with him.

But the true discoverer of the practical application of coal-gas for lighting purposes was Mr. MURDOCH, a Scotchman, who, in the year 1792, while at Redruth in Cornwall, made a series of experiments on the quantity and qualities of the gases produced by distillation from different mineral and vegetal substances. He was induced, by some observations which he had previously made on the burning of coal, to try the combustible properties of the gases produced from it, as well as from peat, wood, and other inflammable substances; and was struck with the great quantities of gas which they afforded, as well as with the brilliancy of the light, and the facilities of its production. He continued his experiments till 1798, when he removed from Cornwall to a situation of importance in BOULTON and WATT's works at Soho, and there he constructed an apparatus which, during many successive nights, was applied to the lighting of their principal building. In the meantime he tried various methods for washing and purifying the gas, and these experiments were continued with some interruptions till the peace of 1802, when a public display of the gas-light was made by him in the illumination of the manufactory at Soho on that occasion. He afterwards extended the same apparatus, so as to give light to all the principal shops in the neighborhood, where it was in regular use to the exclusion of other artificial light; and, finally, in 1808, he fitted up the gas apparatus in Messrs. PHILLIPS and LEE's cotton mill; from which time it gradually extended to all the cotton mills in the kingdom.

At the same time, much credit is due to Mr. WIN-SOR, who took out a patent for a similar process in 1806, delivered lectures on the subject, and endeavored to get up a joint-stock company for street-illumination. In this object he did not succeed till 1812, when some of the streets of London were first lighted with gas. Oil-gas was first prepared on a large scale by PHILIP

TAYLOR, who erected the gas-works at Paris soon after the peace of 1815.

NATURE OF ILLUMINATING GAS.—KNAPP justly remarks that the lighting properties of a gas, or mixture of gases, must depend upon the relation which the carbon in it bears to the hydrogen, and that it can only be turned to a useful purpose when there is more of the former of the two elements present than in fire-damp, and when the proportion of both approaches that of olefiant gas. Light carbide of hydrogen— C_2H_2 —contains 75.4 carbon to 24.6 hydrogen; olefiant gas— C_2H_4 —consists of 86 carbon to 12 hydrogen.

The illuminating power of different carbides of hydrogen varies considerably. Fire-damp contains one part by weight of hydrogen to three of carbon; but one part of hydrogen requires eight, and one part of carbon 2.666 parts of oxygen for combustion; now, supposing the oxygen of the air, which performs an important part in combustion, to combine with both simultaneously—then, as eight parts of oxygen consume one of hydrogen, just eight parts of oxygen would unite with the carbon, and consume three parts, or exactly the whole quantity. In olefiant gas, there is one part of hydrogen to six of carbon; therefore, under the same supposition, one part of hydrogen and three parts of carbon will be consumed together, whilst as much carbon, or three parts, will be set free. Although in reality the hydrogen is always consumed first, yet it is obvious that olefiant gas is capable, under similar circumstances, of supplying more carbon to the flame, and, consequently, of producing more light, and it would have a decided preference above all others, if it could be procured sufficiently cheap. This, however, is not the case, and one must be satisfied, from economical motives, with a mixture of gases, or, in other words, a compound gas, produced by the decomposition of certain substances of organic origin, and containing so much olefiant gas that it far exceeds carbide of hydrogen in illuminating power. When these organic substances are exposed to a certain temperature, the following process results. Certain volatile products escape, which partly condense on cooling into tar and aqueous fluid, whilst the rest is a mixture of gases, but contains likewise no small portion of the volatile vapors of different compounds, which remain dissolved in the cooled gases, without being condensed into liquids. A coaly residue which is termed *coke* is left.

The researches of numerous chemists upon coal tar, have led to the discovery of oily volatile products of very different chemical character, and which are chiefly carbides of hydrogen, with a very large proportion of carbon. To this class belong *anilin*, *leucolin*, *pyrrol*, *rosolic*, *brunolic*, and *carbolic acids*, and *naphthalin*. Most of these contain ninety per cent. of carbon, naphthalin as much as ninety-four; and in burning they deposit it in still greater quantity than olefiant gas. It is, therefore, easily conceived why the vapors of these substances remaining with the gas, so very much enhance its value. Such mixtures of gas and vapor are termed illuminating gas, without reference to the separation of noxious and useless impurities before it is used. Gas, consequently, is not a definite compound of light carbide of hydrogen or olefiant gas, but more

properly a mechanical mixture of very various bodies, some being only slightly or not at all luminous, whilst others are exceedingly so, as olefiant gas and the other carbides of hydrogen which possess similar properties, and to which the whole is indebted for its illuminating power. It is a remarkable circumstance, that carbon and hydrogen are capable of uniting in the same proportions by weight to form a series of gases and liquids, which only vary on account of the different amount of contraction of volume which their elements undergo in the moment of combination; and this alone can explain the great multiplicity of solid, liquid, and gaseous carbides of hydrogen which are known to exist.

It may be conceived that different substances, as wood, fat, and coal, must be suited in different degrees for the production of light-gas. Coal, fats, or oils, resin and tar, asphaltum, soap-water, and the refuse of animal bodies, are all practically employed, according to the locality, in the production of gas. The different nature of these bodies requires that different modes of preparing the gas from them should be adopted, and these will be considered separately further on.

The amount of gas from a given quantity of coal depends greatly upon its quality, and the manner in which its distillation is conducted; it is, therefore, very variable.

Experience has proved that English cannel is the best gas-coal, both as regards the quantity and quality of the gas which it yields. Scotch parrot coal comes next. Even the Berlin gas-works use cannel coal from England. In France, where cannel is not to be met with, highly caking coal of a similar character is selected, and on the East coast of England, caking coal is generally employed for the production of gas.

ACCUM found that one hundred cubic feet of coal gave from eighteen thousand seven hundred to nine thousand two hundred cubic feet of gas, according as the best kinds of Scotch or Lancashire coal were used, or the inferior sorts of Staffordshire. At the hospital at St. Louis, at Paris, the yearly average, from the same amount of coal, was twelve thousand three hundred cubic feet of gas, which is equal to four hundred and ninety-three cubic feet of gas to the hundredweight of coal. PRECHTL estimates the produce at seven hundred cubic feet; so that the statements as regards the weight of gas vary from twelve to seventeen per cent.

The decomposition of the coal begins with the incipient red heat of the enclosing vessels, and continues, if large quantities are employed, several hours, the quantity of gas gradually decreasing towards the end. PECKSTON found that, in an eight hours' distillation, when the fire was uniform, and the vessels constantly red hot, the relative quantities of gas given off were, in the first hour, twenty; in the second, fifteen; in the third, fourteen; in the fourth, nearly thirteen; in the fifth, twelve; in the sixth, ten; in the seventh, nine; and in the eighth, about eight per cent. of the whole quantity. The cubic foot at the end, therefore, costs two and a half times as much as at the commencement. The quality of the gas, at the different periods of the distillation, however, must also be taken into consideration. For this purpose, it will be proper to glance at the ingredients of the gaseous mixture in

general, which, after the separation of the aqueous fluid and the tar, consists of—

Hydrogen,.....	H
Bihydride of carbon,.....	C H ₂
Olefiant gas,.....	C ₂ H ₂ , or C ₃ H ₄
Volatile hydrocarbon,.....	C ₃ H ₈
Benzol,.....	C ₁₂ H ₈
Carbonic oxide,.....	C O
Cyanogen,.....	C ₂ N
Sulphide of hydrogen,.....	H S
Ammonia,.....	N H ₃
Carbonic acid,.....	C O ₂
Sulphurous acid,.....	S O ₂
Bisulphide of carbon,.....	C S ₂
Nitrogen,.....	N

The carbonic oxide and a part of the free hydrogen, doubtless, have the same origin, being formed from the moisture in the coal, or from the first portions of aqueous vapor generated, which, passing over the incandescent coke, are converted into these gases. The nitrogen of the coal is obtained entirely as cyanogen and ammonia, partly in combination, and the latter is also found with the sulpho-cyanogen and the other acids, forming volatile salts; *free* nitrogen, on the contrary, is the residue of atmospheric air contained in the retort. Sulphide of hydrogen and sul-

phurous acid arise from iron pyrites, eviscerated by the coal.

The first four of the ingredients named, with the illuminating vapors of tar oil, form the proper bulk of the gas; the others are small quantities of impurities which should have been separated with the tar. Experiment has proved that the relative proportions of the four principal ingredients vary with the duration of the distillation. When chlorine is added to light-gas and the vapors of tar oil, a fluid compound separates, and the original volume is consequently lessened. The diminution which the volume of the gas suffers when mixed with chlorine is, therefore, in direct proportion to its illuminating power and to the value of the gas—the amount of olefiant gas and tar oil vapors which it contains. This explains the following results of a series of elaborate experiments by Dr. HENRY, who followed analytically, step by step, the whole course of the evolution of gas. He found that, at incipient redness, scarcely anything but hydrogen, atmospheric air, and some tar passed off, with hardly any illuminating gas; but that, after attaining that temperature, illuminating gas alone appeared, and this was composed of a mixture of gases in the following relative proportions:—

Time of collection	Specific gravity	Out of a hundred parts of gas from Wigan canal coal.				
		Chlorine absorbed	Carbide of hydrogen absorbed	Carbonic oxide absorbed	Hydrogen absorbed	Nitrogen absorbed
In the first hour,.....	0.650	13	82.5	3.2	0	1.3
.....	0.620	12	72	1.9	8.8	5.3
.....	0.630	12	58	12.3	16	1.7
Five hours after the commencement,.....	0.500	7	56	11	21.3	4.7
Ter do. do.	0.515	0	20	10	60	10

Consequently, as a general result, carbide of hydrogen is formed in decided excess, and the most luminous portion of this, which is condensable by chlorine, comprises only about one-fifth of the whole. These numbers also prove distinctly, that after about the fifth hour the quantity only increases, but the quality does not improve; indeed, this deteriorates so rapidly, that at the expiration of ten hours, the gas which passes over is hardly luminous when ignited, but burns with a very faint flame. The specific gravity, as will be seen, keeps pace with the quality of the gas, diminishing as the latter improves, and can thus far be taken as a test for its value. As pure olefiant gas has about the specific gravity of common air, 0.98, the density of the illuminating gas must increase with the quantity of olefiant gas contained in it; yet an extraordinary amount of carbonic oxide, specific gravity 0.97, or of carbonic acid, specific gravity 1.52, may give rise to errors of some magnitude.

The great increase of hydrogen, which at the last period amounts to sixty per cent., is remarkable, and important to the manufacturer—an augmentation which is no longer due to the decomposition of aqueous vapors, but to that of the carbides of hydrogen. It was long ago observed that these are decomposed at a bright red heat, and deposit a portion of their carbon on the sides of the vessels. MARCHAND's recent experiments show very clearly the progress of this decomposition.

When olefiant gas was conducted through a red-hot

tube, and the heat constantly elevated, the gas passing off, collected in successive portions, contained the following quantities of carbon to one hundred of hydrogen:—

H ₂ hydrogen	Carbon	Nature and temperature of the gas.
100	614	Olefiant gas.
100	580	Red heat.
100	533	—
100	472	—
100	367	—
100	325	Intense white heat.
100	307	Light carbide of hydrogen.
100	7	Continued white heat, nearly pure hydrogen.

The Editor will now give a short account of each gas, with its preparation and properties.

HYDROGEN.—First in the table of the constituents of coal-gas is this element, which in its pure state is a colorless transparent gas, possessing a very low specific gravity. It may be obtained by the action of weak sulphuric acid upon iron or zinc. Some nails, or pieces of iron wire, or granulated zinc, may be introduced into a tubulated flask, and covered with sulphuric acid, diluted with six or eight times its bulk of water; an effervescence ensues, heat is evolved, and the gas escapes, which may be collected in the hydro-pneumatic trough. The hydrogen, however, which is thus eliminated, is never perfectly pure. When procured from iron, its smell is peculiar and disagreeable, in consequence, according to BERZELIUS, of its

containing a portion of volatile oil, formed by its union with a minute quantity of carbon, which all common iron contains. When such gas is passed through alcohol, much of the odor is absorbed by it, and on diluting it with water, it becomes milky. Obtained by means of zinc, the gas is perhaps somewhat more pure, but appears to hold a trace of zinc and of carbon in solution, and perhaps, in some cases, traces of sulphur and of arsenic. For the purposes of delicate experiments, hydrogen must be passed through a solution of potassa, and then exsiccated by conducting it over fragments of fused chloride of calcium; it should also be collected over mercury, and procured from *purified zinc*, and *pure* sulphuric acid, so far diluted as to act but slowly upon the metal.

Hydrogen is an uncondensable aeriform fluid; it is not absorbable by water, unless that liquid has previously been deprived, by long boiling, of common air, in which case a hundred cubic inches dissolve about 1.5 of the gas. It has no taste, and when perfectly pure is inodorous. It has great power of refracting light. It may be respired for a short time, though it is instantly fatal to small animals. M. MACNOIR, after having breathed a quantity of this gas, found that his voice had become remarkably shrill. The intensity of sound is greatly diminished in an atmosphere of hydrogen; LESLIE, indeed, ascertained it to be more feeble than its rarity, compared with air, would have led him to expect. He placed a piece of clockwork, by which a bell was struck every half minute under the receiver of the air-pump, and after exhausting the air, filled the receiver with hydrogen; but the sound was then even feebler than in the highly rarefied atmosphere.

Hydrogen gas, says BRANDE, is the lightest known form of matter, and its equivalent, combining, or atomic weight, is below that of all other substances; it is, therefore, conveniently assumed as *unity* in reference to the *atomic weights* of all other bodies. In consequence of its extreme lightness, it is difficult directly to determine its weight with accuracy by the common process; but the researches of BERZELIUS and DULONG, and of Dr. PROUT, lead one to infer that its specific gravity, compared with oxygen, is as one to sixteen; one hundred cubic inches, therefore, of pure hydrogen gas at mean temperature and pressure, weigh only 2.1483 grains, and compared with air, its specific gravity would be nearly as seven to one hundred, or, more correctly, as 0.0694 to unity.

The low specific gravity of this gas is well and interestingly illustrated, by substituting it for common air in soap bubbles, which then rapidly ascend in the atmosphere, and may be kindled by the flame of a taper. The same circumstance also leads to its employment for the inflation of balloons, which, however, have of late years been generally filled with coal-gas. Small balloons may be purchased made of gold-beater's skin, or the lining membrane of the crop of a turkey, which, when filled with pure hydrogen, rise to the ceiling, their specific gravity being inferior to that of the surrounding air. Some of these, when filled with hydrogen, do not weigh more than forty-two grains, while the same bulk of air would weigh fifty-two, so that their buoyant power is about ten grains.

Hydrogen is inflammable, and extinguishes flame. When pure, it burns quietly, with a pale yellowish flame at the surface in contact with air.—*Brande*.

BIHYDRIDE OF CARBON—light carbide of hydrogen—is produced collaterally with carbonic acid, in the putrefaction of vegetal substances under water—hence its name, *marsh-gas*. It burns with a pale bluish light, rather stronger than hydrogen.

This gas is best obtained for experimental purposes by the decomposition of *certain acetates*, under the following conditions, first pointed out by PERSOZ, and described by DUMAS: forty parts of crystallized acetate of soda, forty of caustic potassa, and sixty of powdered quicklime, are well mixed and heated in a glass retort; the use of the lime being to prevent the action of the alkali upon the glass; at a heat approaching dull redness, the gas is abundantly evolved, and may be collected over water. The action is determined by the affinity of the alkaline bases for carbonic acid, and the instability of the acetic acid at high temperatures, an equivalent of acetic acid and one of water producing carbonic acid, which combines with the soda and potassa, while, at the same time, light carbide of hydrogen is formed, and passes off, as shown by the following formula:—



A mixture of one equivalent of fused hydrate of baryta, and one of anhydrous acetate of soda, similarly treated, also yield a pure gas.

Sir H. DAVY found the specific gravity of this gas to be 0.555, and, compared with hydrogen, as eight to one. One hundred cubic inches weigh 17.4 grains. According to FARADAY, its refractive power is 2.097, air being 1.000. When pure, it is of course unrespirable, but it is not very noxious when mixed with air. It is sparingly soluble in water, fourteen cubic inches of which take up about one of the gas. It is hardly, sensibly soluble in alcohol or ether, and in oil of turpentine the proportion dissolved is not probably one-fiftieth of the volume of the fluid employed. It is inflammable, burning with a yellow flame, and producing carbonic acid and water; it has, when quite pure, scarcely any odor. It is not decomposed by electric sparks, but, when passed through a white-hot tube, deposits a portion of its carbon.

A hundred volumes of this gas require two hundred of oxygen for perfect combustion, which produces water and a hundred volumes of carbonic acid. One hundred volumes of carbonic acid contain a hundred of oxygen, or half the quantity consumed; the remaining hundred volumes, therefore, must have united with two hundred of hydrogen to form water; hence, this gas is composed of—

	Atomic weight	Per cent.
1 Eq. of Carbon,	6	75
2 Eqs. of Hydrogen,	2	25
1 Eq. of Bicarbide of hydrogen, ...	8	100

DAVY made several experiments on the combusti-

bility and explosive nature of this gas. He observed that when one volume was mixed with one of air, they burned by the approach of a lighted taper, but did not explode; two of air and three of the latter to one of gas manifested similar results. When four of air and one of the gas were exposed to a lighted candle, the mixture being in the quantity of six to seven cubic inches in a narrow-necked bottle, a flame descended through the mixture, but no noise was produced; one volume of gas, burned with six of air in a similar bottle, made a slight whistling sound; one of gas with eight of air, rather a louder sound; one with ten, eleven, twelve, thirteen, and fourteen still inflamed, but the violence of the combustion decreased. A candle burned in a mixture of one of gas and fifteen of air, with a greatly enlarged flame, without producing explosion. The compound which appeared to be of the greatest explosive power, was that of seven or eight volumes of air to one of gas; but the report produced by fifty cubic inches of this mixture was less than that resulting from one-tenth of the quantity of a mixture of two parts of atmospheric air and one of hydrogen.

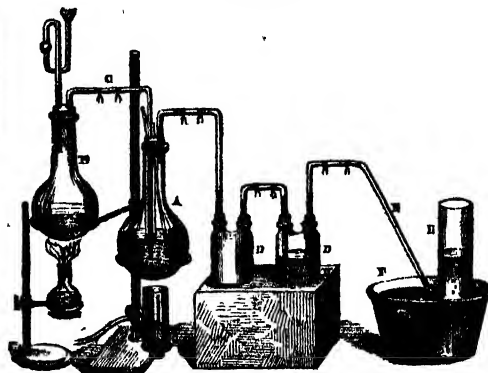
In reference to the *degree of heat* required to explode this gas mixed with its proper proportion of air, it was found that a common electrical spark would not explode five parts of air and one of the gas, though it exploded six parts of air and one of the gas; but very strong sparks from the discharge of a Leyden jar seemed to have the same power of exploding different mixtures of the gas as the flame of the taper. Well-burned charcoal, ignited to the strongest red heat, did not explode any mixture of air and of the fire-damp; and a fire made of well-burned charcoal, that is, charcoal that burned without flame, was blown up to whiteness, by an explosive mixture containing the fire-damp, without producing its inflammation. An iron rod at the highest degree of red heat, and at the common degree of white heat, did not inflame explosive mixtures of the gas; but when in brilliant combustion, it produced the effect. The flame of gaseous oxide of carbon, as well as that of olefiant gas, exploded the same mixtures.—*Brande*.

OLEFIANT GAS.—Next in order is the chief constituent of coal-gas—namely, olefiant gas, a name derived from its property of producing, when in contact with chlorine at the common temperature, a peculiar aromatic oil resembling chloroform.

This gas burns with a beautiful brilliant flame, constituting the true illuminating principle of coal-gas. It is generally obtained by decomposing alcohol by sulphuric acid; for which purpose, two parts by measure of the acid, and one of alcohol, are put into a retort, and heat applied; soon after the mixture boils, the gas is evolved. It may be collected over water, and should be well washed with lime water, or with a solution of potassa, to abstract sulphurous and carbonic acids; it also retains a little ethereal vapor, which may be removed by agitating it with weak alcohol, and afterwards with water. A more refined process for the production of olefiant gas is that of *MITSCHELICH*, which consists in passing the vapor of alcohol into sulphuric acid, so far diluted as to have its boiling point reduced 325° —namely, about two parts vitriol,

specific gravity 1.8, and one of water. The acid is heated to the boiling point, or nearly so, and is then put into the receiver, A, Fig. 89. The flask, or tubulated retort, B, contains alcohol. On the application

Fig. 89.



of heat to the latter, its vapor passes, by means of the tube, C, into the hot acid, and is converted—catalytically—into olefiant gas and aqueous vapor, which, after passing through a Woulfe's apparatus, D D, escape by the tube, E, together with a little alcohol and ether, into the pneumatic trough, F. The gas continues its course upwards into its recipient, H, while the accompanying bodies just mentioned are condensed in the trough. By this process the acid is not discolored, and no sulphurous acid is formed.

The apparatus may be variously modified. Thus, when it is required that the whole of the alcoholic vapor should be transformed into the olefiant gas, the ebullition of the acid must be continued by means of a spirit or gas lamp placed under the receiver. When the acid is merely heated in the first place, decomposition proceeds only till the acid is cold. Still, for preparing a *small quantity* of gas, this condition is quite sufficient.

The specific gravity of olefiant gas, as usually prepared, is about 0.980, or, compared with hydrogen, as fourteen to one, and a hundred cubic inches weigh about thirty grains. According to *THOMSON*, its specific gravity is 0.9722—the same as that of nitrogen and carbonic oxide—and a hundred cubic inches at the temperature of 32° weigh 31.879 grains. Its refractive power is 1.818, air being one; and its specific heat, compared with that of air, is, according to *DULONG*, 1.53, and according to *DE LA ROCHE* and *BERARD*, 1.55, being greater than that of any other gas.

Under the combined influence of intense cold and pressure, *FARADAY* succeeded in condensing olefiant gas into a clear, colorless, transparent liquid, not solidifiable: its vapor exerts a pressure of 26.9 atmospheres at 0° .

Olefiant gas, when carefully purified, has little odor, though it is very difficult to get rid of traces of ether; it is inflammable, burning with a bright and highly luminous flame. It extinguishes a taper, and is quite irrespirable. Water absorbs about one-eighth its volume of olefiant gas, leaving an insoluble residue, which burns like light carbide of hydrogen.

MARCHAND states that one volume of olefiant gas requires, for perfect combustion, three of oxygen. When sulphur is heated in one volume of this gas, charcoal separates, and two volumes of sulphide of hydrogen result. As hydrogen suffers no change of volume by combining with sulphur, it follows that olefiant gas contains two volumes of hydrogen condensed into one; hence the quantity of oxygen required for its combustion. This compound is also decomposed by heat alone, as by passing and repassing it through a red-hot tube of earthenware or metal; it then gradually deposits its carbon, and is ultimately expanded into twice its original volume of pure hydrogen. An analogous transformation of the olefiant gas generated in the retorts of the gas-works is observed, and is connected with the deposition of several interesting forms of carbon.

When *one* volume of olefiant gas is detonated by the electric spark in a proper tube—which, on account of the violence of the explosion, should be very strong—with three volumes of oxygen, *two* of carbonic acid are formed, and water is deposited. Now two volumes of carbonic acid contain two of oxygen, so that the other volume of oxygen must have condensed two of hydrogen to form water. Hence *one* equivalent or volume of olefiant gas must contain *two* equivalents of carbon and *two* of hydrogen.—*Brande*.

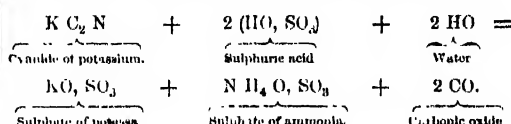
VOLATILE HYDROCARBONS.—Next in order, among the constituents of coal-gas, are the volatile hydrocarbons, portions of which vaporize at a heat much below that of boiling water; consequently, parts of them are carried off by the coal-gas—the quantity found in the gas varying with the distance from the works in which it is generated.

BENZOL contains ninety-two per cent. of carbon, a far greater amount than even olefiant gas. When it is burned with an insufficient supply of oxygen, large deposits of carbon ensue. With a proper quantity of oxygen, this hydrocarbon affords a beautiful light, as may be observed when a stream of atmospheric air is transmitted through it during ignition. The peculiarly rich and illuminating power of the vapor of benzol, may be seen by passing it through the pale and almost invisible flame of hydrogen. This substance has been fully described in Vol. I., page 285, *et sequitur*.

CARBONIC OXIDE, which is rather an impurity than a proper constituent of coal-gas, may be very readily obtained, as *BRANDE* remarks, by *DUMAS'* process, which consists in gently heating oxalic acid with five or six times its weight of sulphuric acid; the mixture effervesces in consequence of the evolution of equal volumes of carbonic oxide and carbonic acid gas; the latter may be abstracted by a caustic alkaline solution, and pure carbonic oxide gas remains. In this case, the evolution of the two gases is caused by the abstraction of water from oxalic acid, which contains, in its anhydrous state, the elements of one equivalent of carbonic oxide, and one of carbonic acid; but these can only exist as oxalic acid when in union with water, or with a base, anhydrous oxalic acid not having been isolated. Crystallized oxalic acid is $C_2O_3 \cdot 3HO$, which, acted upon by three equivalents of sulphuric acid, $3(HO, SO_3)$, becomes $3(2HO, SO_3) + CO_2 + CO$;

the hydrated sulphuric acid remains in the retort, the carbonic acid is abstracted by passing the gases through a solution of caustic potassa, and the carbonic oxide passes off. Another source of carbonic oxide, suggested by *TOWNES*, is the action of ten parts of concentrated sulphuric acid on one part of pulverized crystals of ferrocyanide of potassium; the gas thus obtained is pure, and is evolved in the proportion of three hundred cubic inches from half an ounce of the salt.

Ferrocyanide of potassium contains cyanide of potassium, $K C_2 N$, and cyanide of iron, $Fe C_2 N$; they are converted by the sulphuric acid into sulphates of iron and potassa, sulphate of ammonia, and carbonic oxide; thus, in regard to the cyanide of potassium,



It not unfrequently happens that carbonic oxide is formed by the combustion of carbon when the supply of oxygen is inadequate to the production of carbonic acid; hence the lambent blue flame which sometimes plays upon a coke or charcoal fire, or is seen to issue from certain furnaces: this is, in fact, equivalent to passing carbonic acid over red-hot charcoal; so that $C O_2 + C$ becomes $2 CO$.

The specific gravity of this gas compared to hydrogen is as fourteen to one; and to atmospheric air as 0.9706 to 1.0000; a hundred cubic inches weighing 29.0979 grains. It is very fatal to animals, causing giddiness and fainting when respired mixed with atmospheric air. When breathed pure, it almost immediately produces profound coma. It extinguishes flame, and burns with a peculiar blue light when mixed with, or exposed to, atmospheric air. *DAVY* found that the temperature of an iron wire heated to dull redness was sufficient to inflame it. It has no taste and little odor; it does not affect vegetal colors, occasions no precipitate in lime water, and is very sparingly absorbed by water which has been deprived of air. When burned in dry air or oxygen under a bell-glass, no moisture whatever is deposited, showing that hydrogen is not contained in this gas. Carbonic acid is the only result of this combustion.—*Brande*.

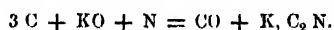
No change is effected in carbonic oxide when it is passed and repassed through a red-hot porcelain tube; nor is it altered at high temperatures by phosphorus, sulphur, nor even, according to the experiments of *SAUSSURE*, by hydrogen, though it is stated upon other authorities, that at elevated temperatures hydrogen does decompose it.

CYANOGEN.—There is no class of organic bodies, remarks *SIR ROBERT KANE*, of which there is more extensive and exact knowledge, than those which have cyanogen as their basis. The powerful affinities which this radical exerts, the simplicity of its constitution, and above all, the circumstance that one is able to prepare it in an isolated state, and to generate its compounds directly from it, as from those of a truly simple body, renders its history the most advanced portion of organic chemistry, and that to which the

analogy of mineral bodies, and the theory of compound organic radicals, is most undeniably applicable.

Cyanogen does not exist in nature ready formed; the kernels of peaches, plums, bitter almonds, *et cetera*; and the leaves of the cherry-laurel, yield, by distillation, abundance of hydrocyanic acid, but it is only then produced by the decomposition of other substances containing nitrogen.

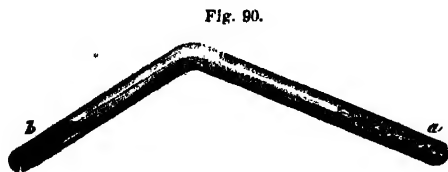
This body may, however, be formed abundantly, and in a simple manner, by bringing its elements together at a high temperature, in contact with substances with which it may unite. Thus, when any organic matter containing nitrogen is calcined with potassa, the nascent carbon and hydrogen unite, and cyanide of potassium is produced; even with pure charcoal this occurs, nitrogen being derived from the air; and FOWNES has shown, that when a mixture of pure charcoal and potassa is ignited in a tube, and a current of nitrogen passed through it, the latter is absorbed, and carbonic acid gas being given off, cyanide of potassium is produced—



This mode of forming cyanogen has been made the basis of manufacturing processes on the great scale, and at present much ferrocyanide of potassium so formed is sent into commerce. By the action of ammonia also on ignited charcoal, cyanogen is generated in abundance; it combines with hydrogen and the excess of ammonia, and produces ferrocyanide of ammonium. It is by virtue of these processes, that cyanogen is obtained for its various applications in the arts.

Cyanide of silver, or cyanide of mercury, is to be introduced into a small glass retort, and heated to just below redness; a gas is evolved which must be collected over the mercurial trough; the cyanide of silver separates simply into metal and cyanogen; but when cyanide of mercury is used, a brown powder appears, the quantity of which is less as the temperature of its decomposition has been lower. The gas which comes over is, however, cyanogen absolutely pure. If a large supply of this gas be required, but not of absolute purity, it may be prepared by mixing boiling solutions of two parts of chloride of mercury, and three parts of ferrocyanide of potassium, and evaporating down the liquor; the dry mass, which is a mixture of cyanide of mercury, chloride of potassium, and cyanide of iron, gives out on the application of heat a very large quantity of cyanogen, nearly pure.

The properties of this gas are very distinct. It is colorless, has a sharp smell, which irritates the eyes. Its



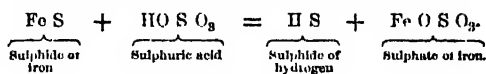
specific gravity is 1.819. If a quantity of cyanide of silver be sealed up in a strong tube, bent as in Fig. 90, and then heated at one end, *a*, the cyanogen is evolved and condensed by a pressure of about four atmospheres, and

collects at the other end, *b*, as a colorless liquid. It is combustible, burning with a beautiful rose-colored flame, and producing two volumes of carbonic acid and one of nitrogen. It is constituted, therefore, of equal volumes of carbon vapor and nitrogen, the two volumes being condensed to one; hence, $0.836 + 0.976 = 1.812$, is its specific gravity. It dissolves abundantly in alcohol and water, but these solutions soon undergo very complex decompositions; the liquor being found to contain carbonic acid, hydrocyanic acid, ammonia, urea, and oxalic acid, besides a brown insoluble matter. A similar decomposition is produced much more rapidly by contact with aqueous ammonia. The composition of this brown matter appears to be $C_4 N_2 H_{10} O$. It dissolves in alkalies, and gives precipitates with the metallic salts; it has been hence termed *azulmic acid*. When heated it gives off cyanogen, which has been termed *paracyanogen*. This may be also formed by heating cyanide of mercury very strongly. It dissolves in hot nitric acid, and the solution gives, with water, a yellow precipitate, which combines with bases.

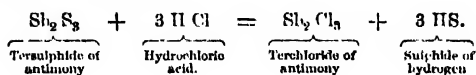
Cyanogen unites directly with hydrogen and with the metals, but its oxygen combinations require to be indirectly formed; there are three compounds of cyanogen and oxygen, which are all acids, and are polymeric bodies. It combines also with sulphur, and its compounds with this element have a remarkable tendency to form double and triple combinations.

The formula of cyanogen is indifferently written $C_2 N$ or Cy . Its equivalent number is 26.—*Kane*.

SULPHIDE OF HYDROGEN is best prepared by acting upon the sulphide of iron with dilute sulphuric acid. A lively effervescence ensues from the escape of this gas, and the solution contains protosulphate of iron; a gentle heat may be applied to facilitate the decomposition. In this process water is decomposed, its oxygen uniting with the iron, and its hydrogen with the sulphur; the change may be represented by the following—



This gas may also be obtained by acting on sulphide of potassium by dilute sulphuric or hydrochloric acid, in which case the result is similar to that already given. Sulphide of antimony and hydrochloric acid produce, when heated, very pure sulphide of hydrogen, the reaction being—



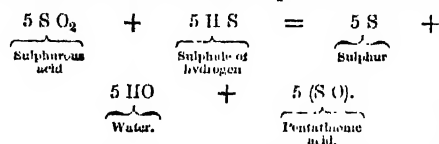
As sulphide of hydrogen is absorbed by water, it cannot well be collected over this liquid, except it be saturated with chloride of sodium, or be heated to above 90° , in which case its solvent power is very much diminished. It cannot be kept long over the mercurial trough, for the lead and tin, always present in the mercury of commerce, gradually decompose it, combining with the sulphur, and leaving the hydrogen free; the volume of the gas remains the same during this chemical reaction.

This gas is colorless and transparent; it is charac-

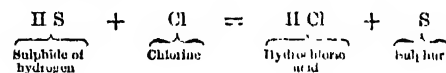
terized by the fetid odor of rotten eggs, which, in fact, owe their peculiar smell to the production of this gas during their putrefaction. Its specific gravity is 1.177.

Sulphide of hydrogen gas dissolves in water, forming a solution used extensively as a reagent for most of the metals, from the solutions of which it precipitates metallic sulphides of various colors, by which many metals are distinguished.

When aqueous sulphide of hydrogen is exposed to the air, oxygen is absorbed, which combines with the hydrogen of the sulphur compound, water being produced, while the sulphur is set free, and appears as a milky precipitate. The nascent sulphur, however, in part absorbs also oxygen, and sulphuric acid is formed; hence the presence of this acid, free, in volcanic springs, as in the Rio Vinaigre in New Spain. If a solution of sulphurous acid be mixed with sulphide of hydrogen, half of the whole quantity of sulphur is precipitated, and the remainder is converted into pentathionic acid—



Sulphide of hydrogen is highly inflammable; if burned in a limited quantity of air, the hydrogen is consumed, whilst most of the sulphur is deposited. By means of chlorine or nitric acid, it may be completely decomposed; hence, chlorine acts as a disinfectant and purifier of sewers or rooms impregnated with the odor of sulphide of hydrogen. The annexed represents the decomposition:—



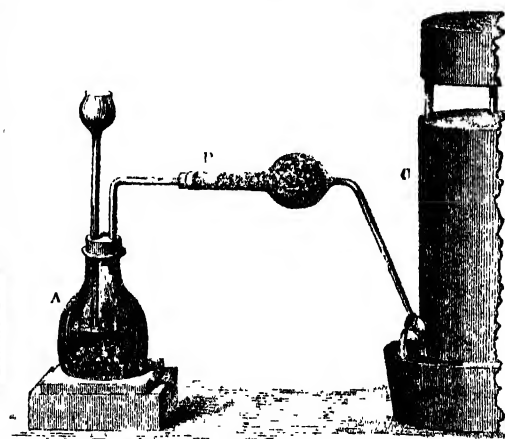
This gas is very poisonous; air containing only one eight-hundredth part producing death. Many of the metals decompose sulphide of hydrogen, particularly when heated in this compound, combining with the sulphur, and setting free the hydrogen. This occurs slowly, even at common temperatures; hence metals, as gold and silver, which are not oxidized by the air, are gradually tarnished by sulphide of hydrogen, which, exhaled from decomposing animal matter, is always present in the atmosphere. This gas, evolved probably by the action of water on the native sulphides of iron, at high temperatures, is a frequent constituent of mineral springs, and forms the class of spas termed sulphurous, such as those of Harrowgate, Lucan, and Golden-bridge. They are easily recognised by the fetid odor, by blackening a silver spoon, or by giving a black or brown precipitate with a solution of a lead salt.—*Kane*.

AMMONIA.—A full description of this volatile alkali is given in Vol. I., page 177, *et sequitur*.

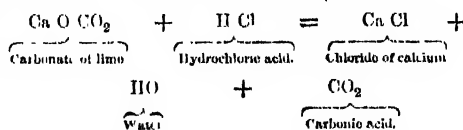
CARBONIC ACID exists in the atmosphere as a product of combustion, and of the respiration of animals. Combined with metallic oxides, it forms the numerous class of native earthy and metallic carbonates, of which the carbonate of lime is much the most important.

It is a result, also, of the slow decomposition of vegetable substances, and is evolved in great quantity from the ground in volcanic countries. In the fermentation of sugar, it is produced in abundance along with alcohol. For the purposes of the chemist, it is generally prepared by decomposing marble, or calc-spar, by means of any strong acid; from its cheapness, and the solubility of the residual salt, hydrochloric acid is generally employed. Some fragments of carbonate of lime being placed in a wide-necked bottle, A—Fig. 91—the acid diluted with its own volume of water, is

Fig. 91.



poured in by means of a funnel, as represented in the figure, and the gas which is evolved is conducted through the tube, B, filled with fragments of recently fused chloride of calcium to remove any moisture. It then passes into the gasometer, C, to be made use of as required. The decomposition is as follows:—



The gas, owing to its gravity, may be received in a wide-mouthed bottle, which in this case is ascertained to be full by applying a lighted taper to the mouth, when it is immediately extinguished.

The properties of this gas are exceedingly striking; it is entirely void of color, and invisible; it is irrespirable, producing, when an attempt is made to breathe it, violent spasms of the glottis. If it be inhaled with air, even in the proportion of one to ten, it gradually produces stupor and death, acting as a narcotic poison. Its specific gravity is 1.511; hence, when disengaged in large quantity, whether by natural operations, or in the process of manufacture, it accumulates in all cavities within its reach, and may cause fatal accidents to animals which enter inadvertently. Workmen engaged in cleaning out dry wells or vaults, or the large vats from which fermenting liquors have been run off, should carefully observe whether a candle can remain for some time burning brightly at the bottom. In volcanic countries, chasms are frequently occupied to the

level of their surface by this gas, exhaled from the ground; and an experiment often shown, to amuse the traveller, consists in walking into such a cavern with a dog, which, holding the head near the floor, is almost instantly asphyxiated by the inferior layer of carbonic acid, whilst men, whose heads are above the level, breathe pure air; the dog, on being thrown into a neighboring pond, recovers from the stupor. Carbonic acid does not support combustion, a burning taper held in a jar of it being instantly extinguished; and the high specific gravity of the gas may be easily illustrated by placing a lighted taper at the bottom of a vessel holding air, and taking in the hand another containing carbonic acid; on inclining the latter, the heavy gas can be poured into that which contains the lighted taper—just as water may be emptied from one vessel to another—and falling to the bottom, extinguishes it.

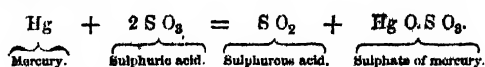
Water absorbs its own volume of carbonic acid gas, forming a solution possessing an agreeably acid taste, and which sparkles when agitated. It changes blue litmus into a wine-red, which, by exposure to the air or heat, disappears. By means of pressure, water can be made to retain a large quantity of this gas, which escapes with effervescence when the pressure is removed, and is thus the basis of a variety of agreeable effervescing beverages. Carbonic acid dissolved in water precipitates solutions of lime and baryta white, forming carbonates, which redissolve in an excess of this acid.

Under a pressure of thirty-six atmospheres, carbonic acid may be liquefied. It then forms a colorless, exceedingly mobile liquid, having a specific gravity 0.83 at 32°, which is remarkable for its excessive expansibility by heat—this being four times that of air, or nearly one per cent. for each degree of Fahrenheit. When the pressure is suddenly removed from the liquid acid, it regains the elastic form with such rapidity, that, in consequence of the amount of latent heat with which the vapor combines, and which is abstracted from the liquid portion, part of it is frozen to a solid. Solid carbonic acid can thus be obtained in large quantity by an apparatus contrived by THILORIEN. It is a white body in filamentous masses, like asbestos; it evaporates but slowly; it is very soluble in alcohol and ether; the latter solution produces by its evaporation the most intense cold known, estimated at *minus* 166°.—*Kane.*

SULPHUROUS ACID exists at ordinary temperatures and pressures in the gaseous form, but is one of the most easily condensable gases. It is always produced when sulphur is burnt in the atmosphere, or in pure oxygen, sulphur being incapable of passing directly into a higher degree of oxidation. In the burning of sulphur, the volume of sulphurous acid gas produced equals exactly that of the oxygen consumed.

When desired pure, it is usually prepared by decomposing sulphuric acid, by means of a metal not very easily oxidized, as mercury or copper. The metal combines with one equivalent of the oxygen of the sulphuric acid, and the sulphur with the remaining two equivalents of oxygen pass off as sulphurous acid gas; the oxide obtained unites with the sulphuric

acid to form a salt. Thus, taking mercury for an instance:—



If the temperature be not elevated beyond 200° in this process, it is black or suboxide of mercury which is produced— Hg_2O —but above that degree the red oxide— Hg O —alone is formed.

Sulphurous acid gas is absorbed by water; and hence, in order to examine its properties in that state, it must be collected over mercury. It is colorless and transparent, having a peculiar irritating odor, and cannot be respired. It is neither combustible, nor a supporter of combustion. It possesses bleaching properties, owing to which it is used in the arts to whiten straw bonnets, corn, silk, sponges, and other substances; if a red rose be exposed to the flame of burning sulphur, it becomes completely white.

When this gas is exposed to a temperature at zero, it condenses into a liquid, which boils at 14°, and produces by its evaporation intense cold.

Water dissolves about thirty-seven times its volume of this gas; the solution possesses the properties of sulphurous acid in a very high degree, and bleaches vegetal colors with great power; when kept for some time it gradually absorbs oxygen, and the sulphurous becomes converted into sulphuric acid.

Sulphurous acid is one of the most feeble acids known, and is expelled from its combinations by almost all acids but carbonic, to which the Editor has shown that it bears a most striking resemblance, and this even extends to the salts of both.

BISULPHIDE OF CARBON.—This remarkable substance is obtained whenever sulphur comes in contact with red-hot charcoal. Procured in this way, it contains an excess of sulphur dissolved in it, and must be purified by redistillation at a very moderate heat; when about nine-tenths have distilled over, by allowing the residue to evaporate spontaneously in a capsule, very fine right rhombic crystals of sulphur deposit.

The bisulphide of carbon is a colorless liquid possessing a very disagreeable alliaceous odor. It does not mix with water, but dissolves in alcohol and ether. Sulphur and phosphorus are soluble in it in large quantity. Its specific gravity is 1.272. It boils at 108°, and forms a colorless vapor, the specific gravity of which is 2.621. From its volatility, it obtained the name of *alcohol of sulphur*. While evaporating, it produces great cold; mercury may be frozen by suspending under the bell-glass a thermometer, the bulb of which is surrounded by cotton moistened with this fluid, and rapidly exhausting the air. It is very inflammable, burning with a blue flame, and producing carbonic and sulphurous acids. If a few drops of it be allowed to fall into a strong bottle containing oxygen, it detonates when touched with a lighted taper, like a mixture of oxygen and hydrogen. When the bisulphide of carbon is heated in contact with a metal, carbon is separated, and a metallic sulphide produced, which proves it to consist of one equivalent of carbon united with two of sulphur.

It is a powerful sulphur-acid, combining with the

sulphides of the alkaline metals, and yielding sulphur-salts, which are crystallizable; with the sulphides of lead, silver, copper, *et cetera*, it forms insoluble compounds, which correspond closely in composition to the ordinary carbonates. This substance, in fact, exactly corresponds to carbonic acid— CO_2 —the sulphur being replaced by oxygen, and hence it is often called sulpho-carbonic acid.—*Kane*.

NITROGEN is one of the two gases that constitute the atmosphere; it serves only to modify the effect of oxygen, and render the air fit and suitable for respiration: it is called nitrogen, from being the basis of nitric acid. It is also called by some chemists *azote*, from its incapability of supporting existence; but the former name is generally used, as a great many other gases have not the power of sustaining life.

Nitrogen exists in great quantity in the atmosphere;



Fig. 92.

it is readily procured by abstracting the oxygen from a confined portion of the air, when nitrogen remains almost entirely pure. Thus, if a small piece of phosphorus laid in a cup, *d*, floating in water, be set on fire, and a bell-glass, *a*, be inverted over it, the phosphorus, in burning, unites with the oxygen of the air, and forms white fumes of phosphoric acid. At first, from the great expansion of the air, caused by the high temperature of the flame, some bubbles escape from under the edge of the glass, but soon, even before the phosphorus ceases to burn, the water begins to rise in the bell, and finally, the clouds of phosphoric acid

gradually dissolving in the water, the residual gas will be found to occupy four-fifths of the original volume of the air, and to be colorless. Any combustible body would answer the same purpose, although not so perfectly as the phosphorus.

Independent of this source of nitrogen in atmospheric air, it may be obtained indirectly from other substances. Thus, most animal matters contain nitrogen in large quantity, united to carbon, hydrogen, and oxygen. If, therefore, some pieces of muscle, or albumen, or gelatin, be boiled in a retort with nitric acid, the oxygen of the latter combines with the carbon and hydrogen of the animal substance, forming different compounds, according to the temperature and the proportions, whilst the nitrogen of both is disengaged.

Nitrogen is a permanent gas, colorless, and transparent; it is absorbed by water only in very small quantity. It is lighter than atmospheric air, its specific gravity being 0.976, air being 1.000. It is characterized by the complete absence of the positive properties which distinguish other gases. Thus it does not support combustion or respiration; it extinguishes a taper, and animals are suffocated in it; but these effects appear to be due only to the absence of oxygen.—*Kane*.

AQUEOUS VAPOR.—It will be necessary merely to allude to the aqueous product of the distillation of coal, which is water holding in solution—

Carbonate of ammonia.
Sulphate of ammonia.
Sulphide of ammonium.
Chloride of ammonium.
Ferrocyanide of ammonium.

Most of these are fully described in Vol. I., page 183, *et sequitur*, and therefore, being only secondary products, need not be further dwelt upon.

OILY MATTERS.—The oily portion consists of—

Liquid.	{ Benzol, Toluol, Cinnol, }	Neutral, {	$\text{C}_{12} \text{H}_6$	} Constituents of naphtha.
			.....	$\text{C}_{14} \text{H}_8$
			.....	$\text{C}_{18} \text{H}_{12}$
Liquid.	{ Anilin, Picolin, Leucolin, Hydrate of Phenyl-acid—	{	$\text{C}_{12} \text{H}_7 \text{N}$	} Constituents of heavy oil of tar.
			.....	$\text{C}_{12} \text{H}_7 \text{N}$
			.....	$\text{C}_{18} \text{H}_9 \text{N}$
			.....	$\text{C}_{12} \text{H}_9 \text{O}_2$
Solid.	{ Naphthalin, Paranaphthalin, Pyren, Chrysen,	{	$\text{C}_{20} \text{H}_{12}$	}
			.....	$\text{C}_{30} \text{H}_{12}$
			.....	$\text{C}_{22} \text{H}_{14}$

The Editor having learnt that the little information with reference to these ingredients, which is given in the treatises on gas hitherto published, has been felt as a want, will now refer to them individually; because, although secondary in point of importance, they are highly interesting, as being so intimately connected with the manufacture of coal-gas, which will constitute the principal subject of this article:—

Toluol.—When tolu balsam is distilled, there passes over a large quantity of benzoic, mixed with a little cinnamic acid, and a yellow liquid, which is a mixture of toluol and benzoic ether. By redistilling this, so as only to collect the portions which pass over between 265° and 285° , a distillate is obtained, which, when deprived of benzoic acid by distillation with solid caustic potassa, possesses the properties which belong to toluol.

It is a colorless limpid liquid, having an odor like benzol, volatile without residue, and boils at 226° ; the density of its vapor is 3.246. When it is acted on by concentrated nitric acid, and water afterwards added, an oily fluid is obtained, which is nitrotoluid, $\text{C}_{14} \text{H}_7 \text{NO}_2$, or, according to the Editor, toluol in which one equivalent of hydrogen is replaced by peroxide of nitrogen. By the action of sulphide of ammonium upon nitrotoluid, a yellow oil, which gradually solidifies into a crystalline mass, is obtained. To this substance, which acts as an *organic base*, the Editor gave the name of toluidin.

It crystallizes from its hot alcoholic solution in large broad plates. It is soluble in pyroxylic spirit, sulphide of carbon, and the fat and volatile oils, with the same facility as in spirit of wine; it is very sparingly soluble

in water; it has a vinous aromatic smell and burning taste; it has no action upon turmeric, but it changes red dahlia paper to green. With nitric acid it produces a fine scarlet color, whereas anilin, so treated, assumes a blue tinge. The extraordinary crystalline tendency which distinguishes the salt of anilin, belongs also to toluidin; its alcoholic solution almost immediately solidifies when mixed with an acid. Its salts are inodorous, and, with the exception of the platinum and palladium compounds, colorless. It gave on analysis the following:—

		Theory	Editor.
14 Eqs. of carbon,	84	78.50	78.53
9 Eqs. of hydrogen, . . .	9	8.41	8.61
1 Eq. of nitrogen,	14	13.09	12.86
1 Eq. of toluidin,	107	100.00	100.00

Cumol occurs with hydrocyanid in Roman cumin oil, which, when distilled in an oil-bath, parts with a volatile acid, the hydrocyanid, at 165°, and in the residue the cumin oil remains as a colorless liquid, retaining a strong odor of Roman cumin oil, and a sharp burning taste; boils at 220°. By the action of cyanide of potassium, cumin oil is converted into a product resembling benzoin; in the air, and by the influence of oxidation, it yields cuminic acid. If cumin oil be boiled a long time with nitric acid, there is obtained nitrocuminic acid.

Anilin.—This base, which has the same constitution as picolin, exists in coal-tar oil, as well as in DIPPEL's oil; that which, by fractional distillation of the mixed bases, passes over at 182° is anilin. If sulphide of hydrogen be transmitted into an alcoholic solution of nitrobenzid, saturated with ammonia, sulphur is separated, and shortly the whole stiffens at 0° to a mass consisting of yellow crystalline needles; if this be heated to 212°, the solution filtered away from sulphur, and the filtrate distilled until the contents of the retort separate into layers, then is the lower one *anilin*, which is purified by distillation. It is a colorless fluid, strongly refracts light, has a penetrating odor, taste sharply burning, specific gravity 1.020, boiling point 182°; easily soluble in cold water, alcohol, and ether; if the aqueous solution be warmed it clouds, a portion of anilin being separated; it does not possess an alkaline reaction, but coagulates albumen; in contact with hydrochloric acid it forms a white vapor. When anilin is exposed to air it absorbs oxygen, and becomes yellow, brown, and resinous. A few drops of fuming nitric acid added to anhydrous anilin produce a fine blue color, which on slightly heating the mixture becomes yellow, and violent action ensues, sometimes followed by explosion; otherwise, the liquor passes through various hues, and crystals of nitropicric acid are ultimately formed. When anilin is added to a solution of hypermanganate of potassa, binoxide of manganese, oxalic acid, and ammonia are formed.

If to a solution of chloroxide of calcium—bleaching powder—anilin be added, a deep violet color is obtained, which in the presence of acids becomes red. By these reactions, anilin is distinguished from the other bases which have the same constitution. With the acids, anilin forms crystallizable inodorous salts, which are soluble in water and in alcohol, and which in the moist

air soon become rosy-red. Anilin precipitates the salts of the protoxide and sesquioxide of iron, alumina, and oxide of zinc. Cyanide, ferrocyanide, and sulphocyanide of potassium, do not react upon salts of anilin; tannin causes a brown precipitate.

Picolin occurs in DIPPEL's oil, as also in coal-tar, and in each part thereof, which, on distillation, goes over first, together with anilin. It is more volatile than anilin, and can, therefore, be separated by fractional distillation; what passes over at 133° is pure picolin. It is a flowing liquid of a strong, penetrating, somewhat aromatic smell, and sharp, burning, bitter taste; still fluid at 17°, boils at 133°, specific gravity 0.955; mixes with water, alcohol, and ether in all proportions; it is not precipitated by a solution of bleaching powder, does not coagulate albumen, reacts alkaline. Nitrate of silver, chlorides of barium and strontium, and sulphate of magnesia, are not apparently affected by picolin; tannin causes a white caseous precipitate. It combines with the chlorides of mercury, platinum, tin, and antimony. If picolin be added to a solution of chloride of gold, fine lemon crystals are obtained. The salts possess the property of crystallizing.

Leucolin or *Quinolin*.—This base is found in the least volatile portion of the basic oil of coal-tar, and is also formed when quinin, cinchonin, strychnin, and thialdin, are heated with potassa. It has a disagreeable odor, and boils at 460°; its specific gravity is 1.081. It neutralizes acids, forming difficultly crystallizable salts. Its refractive and dispersive power is as high as that of bisulphide of carbon.

Hydrate of Phenyl, or *Carbolic acid*.—LAURENT obtained from that portion of the oil of tar which boils between 300° and 400°, *carbolic acid*, a compound which it has been found convenient to represent as the hydrated oxide of a radical which has been termed *phenyl*. It is obtained by agitating the oil with about twice its volume of *aqua potasse*, pouring off the watery portion, and saturating it by hydrochloric acid. The carbolic acid separates in the form of a heavy oil, which may be purified by continuous distillation over a small quantity of caustic potassa.

Hydrate of phenyl is a colorless oily liquid, neutral to litmus paper, of a high refractive power, specific gravity 1.062. It has a penetrating odor, a pungent burning taste, and acts powerfully on the skin; it occasionally assumes the form of acicular crystals, which fuse at 94° and boil at 368°. It is slightly soluble in water. It forms crystallizable salts with the alkalies, which, however, retain an alkaline reaction; in many of its properties it resembles creasote. It unites with sulphuric acid to form sulphocarbolic or sulphophenic acid; with chlorine, bromine, and nitric acid, it yields various compounds.

Naphthalin is readily procured by the distillation of coal-tar, but its quantity is considerably enlarged if chlorine be transmitted into the menstruum, or if the latter be treated with bleaching powder, water, and sulphuric acid. Naphthalin always passes over last in the distillation of tar, mixed, however, with paranaphthalin, from which it is separated by treatment with alcohol, in which menstruum the latter is insoluble;

both bodies are deposited if the distillate be cooled to 10°. Naphthalin is purified by recrystallization from the hot alcoholic solution; it crystallizes by slow evaporation in thin, white, rhombic leaflets, and by slow sublimation in white, extremely light flakes of peculiar odor, and burning aromatic taste; insoluble in water, readily soluble in alcohol, ether, acetic acid, and a solution of oxalic acid; melts at 79°, boils at 212°; specific gravity 1.045. Easily distils with vapor of water is inflamed with difficulty, and burns with a sooty flame.

Paranaphthalin or *Anthracin*, which is found in coal-tar, is obtained by the method given in connection with naphthalin. It is procured pure by repeated distillation. Its properties are similar to those of naphthalin, but it does not fuse below 300°; completely sublimable; insoluble in water, scarcely soluble in alcohol or ether, but easily in oil of turpentine. If anthracin is boiled for a few minutes with nitric acid, it is converted into a yellow mass accompanied by evolution of nitrous acid; the mass stiffens after cooling, and if it be then washed with water and treated with ether, a substance remains which has not been thoroughly investigated. This body melts at a high temperature, and by cooling congeals to a mass consisting of long needles.

Pyren is isomeric with anthracin, and is found in tar from wood, coal, and oil. If the last be distilled until one-fourth remains, and the residue again submitted to distillation in a small retort until there is only carbon left, a reddish substance is obtained, which consists of pyren, chrysen, and empyreumatic oils; if this mixture be treated with ether, the chrysen remains, and if the ethereal extract be slowly evaporated, the pyren is then precipitated. It crystallizes from the boiling alcoholic solution in clear rhombohedral prisms; melts at 170° to 180°, and stiffens crystalline; inodorous, tasteless; insoluble in water, little soluble in ether and alcohol; on the contrary, readily soluble in oil of turpentine. Boiled with nitric acid it gives a combination, which consists of $C_{30} \left\{ \begin{array}{l} H_{10} \\ 2 NO_4 \end{array} \right.$ *id est*, pyren, in which two equivalents of hydrogen are replaced by two of peroxide of nitrogen.

Chrysen.—The production of this body is stated in connection with the preceding; it appears as an inodorous and tasteless powder; insoluble in water and alcohol, and scarcely soluble in ether and oil of turpentine; fuses at 230° to 235°; solidifies crystalline. If it be boiled with nitric acid, it is completely dissolved, and a compound results, the composition of which is doubtful, but the Editor is of opinion that it must have the formula $C_{42} \left\{ \begin{array}{l} H_{18} \\ 2 NO_4 \end{array} \right.$.

Besides these, there are various undescribed oils. Of these products, which are all contained in tar, it will be perceived that there is only oxygen in one, and this possesses acid properties. The first three are neutral, and constitute rectified coal naphtha. Three are alkaline, and contain nitrogen. The other four are solid and neutral. It is remarkable how few of the products of distillation have any oxygen, and how much they differ in this respect from those of wood; and that, where the oxygen does enter into combination, it

produces compounds having no illuminating properties, namely, carbonic oxide, carbonic acid, and water; and that, in one instance, it unites with a compound of carbon and hydrogen, producing an acid oil that is found in very small quantity in the tar.

The nitrogen of the coal forms ammonia, cyanogen, and a few alkaline oils; the latter is discovered in minute quantity in the tar. The products are nearly all compounds of carbon and hydrogen; and respecting these it is further to be observed, that when the hydrogen exists in greater quantity than the carbon, as in carbide of hydrogen, which contains two equivalents of hydrogen to one of carbon, the compound is permanently gaseous; this gas has been subjected to a pressure of thirty-two atmospheres, and to cold 166° below zero, without liquefying. Olefant gas, in which carbon and hydrogen exist in equal proportions, but in which two volumes of hydrogen and two of carbon are condensed into one volume, is durably gaseous; $C_{18} H_{12}$ is liquid; whilst naphthalin, $C_{20} H_8$; paranaphthalin, $C_{30} H_{12}$; pyren, $C_{16} H_8$; chrysen, $C_{12} H_4$, are solid. It may be safely asserted, that where the carbon and hydrogen exist in an equal number of equivalents, the compound will be gaseous, unless a very large number enters into the combination.

CHOICE OF GAS COAL.—What, then, are the practical inferences to be drawn from these statements? In the first place, it will be manifest that the greater the quantity of hydrogen, and the less oxygen and sulphur a cannel or coal may contain, the better it will be for gas making; for the latter two rob the coal of a portion of its hydrogen, which is thereby prevented from uniting with a portion of carbon for the production of an illuminating gas. The coal should be selected as free from iron pyrites and sulphate of lime as possible, and lumps or masses of these should be thrown out, as they often occur in such a form in the coal.

EFFECTS OF WATER.—The coal should be moderately dried before being used, which can only be secured by its being stacked under cover, otherwise the rain would keep it saturated with moisture. The water, in its decomposition in the retorts, furnishes oxygen to the carbon of the coal, impoverishing the gas, whilst the hydrogen of the water does not combine with the carbon of the coal, but is liberated.

When the vapor of water is passed over red-hot coke and coal, and analysed, the resulting gas is found to consist, in a hundred volumes, of fifty-six of hydrogen, twenty-nine of carbonic oxide, 15.8 of carbonic acid, and light carbide of hydrogen only two-hundredths of one per cent. *It contains no olefant gas whatever*; this experiment is quite conclusive against the use of water or steam. It is evident that there are no products of the decomposition of water by red-hot coal or coke that possess any illuminating power. It has often been proposed to *pass steam into the retorts during the distillation of coal, but such a proceeding could have no good effect, but the contrary*. When it is considered that fifty per cent. of the whole of the gases proceeding from the decomposition of water by red-hot carbonaceous matter is hydrogen, it must be evident that this product would not only diminish the light of the gas with which it was mixed, but would give out such an

amount of heat during the burning of it as would render the use of such gas almost insupportable. The coal, then, should be dry; but it has been shown that air, passed between seams of coal, has been deprived of a portion of its oxygen, which must have combined with the carbon and hydrogen of the coal, and by so much have impaired its quality; further, it has been stated that coal and cannel are continually giving off gas—fire-damp—and this teaches that coal should be dried quickly and then used.

DISTILLATION OF COAL.—A few remarks may now be made on the changes which take place during the manufacture of gas by the distillation of coal in red-hot retorts. The nitrogen in gas is *entirely derived from atmospheric air*, admitted into the retorts during the charges, and by leakage in the apparatus, and is not a product of the decomposition of coal at all; it need not, therefore, be further dwelt upon.

The quality and illuminating power of the gas will be affected, not only by the quality, composition, and condition, wet or dry, old or recently obtained, of the coal or cannel, but by the degree of heat employed in its preparation, and the mode in which the operation is conducted. The chief products of the distillation are compounds of carbon and hydrogen, and these alone yield light; but of these, some are solids, others liquids, and some gaseous. The first two are of no value for the purpose of illumination, because their physical condition as solids and liquids precludes their use. The gaseous are three: one containing very little carbon—carbide of hydrogen—and, therefore, emitting very little light; the other two very rich in carbon—olefiant gas and volatile carbides of hydrogen—and giving light, though in small quantity. Mixed with these are found, besides the usual impurities—sulphide of hydrogen, ammonia, carbonic acid, *et cetera*—two gases, hydrogen and carbonic oxide, constituting the chief bulk of the mixed coal gas, which have been mentioned, but which are never evolved in natural operations. They are not necessary products of the process, but result from the mode of distillation.

The volatile hydrocarbons in coal gas, the exact nature of which has not yet been determined, and the proportions of which in the mixture are valuable, probably consist of propylene, C_3H_6 , FARADAY's gas, C_4H_6 , and benzol, $C_{12}H_6$, with perhaps a portion of MANSFIELD's allyl. In LEIGH's earlier experiments on coal gas, which had been made from a different cannel to what is now employed at the Manchester Gas-Works, he found, pretty uniformly, that each volume of the gas, condensable by sulphuric acid or chlorine, required four and a half volumes of oxygen for combustion; subsequently, he ascertained that, when richer cannels were used, the condensable gases required a still larger proportion of oxygen for combustion. The fact, that a greater amount of carbonic acid is produced on exploding the gas with oxygen, than would proceed from a body of the series C_nH_n , shows that some other hydrocarbon, the carbon of which exists in a greater ratio to the hydrogen than in this series, is to be found in coal gas.

When the number of equivalents of carbon in a compound exceeds those of the hydrogen, it is, within cer-

tain limits, liquid: beyond these limits, solid: thus benzol, $C_{12}H_6$, in which the carbon is double the hydrogen; toluol, $C_{14}H_8$; and cumol, $C_{16}H_{12}$, are liquid;—whilst naphthalin, $C_{20}H_8$; paranaphthalin, $C_{30}H_{12}$; pyren, $C_{22}H_{12}$; and chrysen, $C_{28}H_{18}$, are solid.

The carbides of hydrogen may be conveniently divided into three classes. In the first, the number of equivalents exceeds that of the hydrogen; they are very rich in carbon, as benzol; these are either liquid or solid, and would give great light could they be burnt, but yield much smoke. In the second, the equivalents of carbon and hydrogen are equal in the compoundly as olefiant gas, volatile carbide of hydrogen; these are gaseous, but condensable by great pressure and intense cold, and give much light. In the third, the equivalents of hydrogen exceed those of carbon; these are altogether uncondensable, and give little light. When coal and similar organic matters are distilled at a comparatively low temperature, the carbon has a disposition to pass off with little hydrogen; the liquid carbides of hydrogen are formed; there is much tar and little gas, but the latter is rich. As the temperature rises, the liquid carbide of hydrogen diminishes in quantity and gaseous carbide of hydrogen increases; there is more gas and less tar. The heat still rising, the gaseous products become richer in hydrogen, and poorer in carbon; light carbide of hydrogen is formed in abundance; and at length, the temperature becoming still more elevated, pure hydrogen is evolved, as is always observed in the last hour's distillation in gas-making.

It is a well-known law of organic chemistry, that the higher the temperature, and the more advanced the decomposition of the substance, the simpler are the products.

When olefiant gas is passed through red-hot tubes, or lime, or, in fact, over any highly heated surface, it deposits a portion of carbon in a solid form, and escapes as a mixture of carbide of hydrogen and hydrogen. The same thing LEIGH has proved of naphtha, which deposits carbon in like circumstances, and is resolved into simple products.

The affinity between carbon and hydrogen seems to diminish with the temperature.

Is it not probable, that in the distillation of masses of coal, compounds rich in carbon are first formed, the carbon being in excess of the hydrogen? as the product rises in temperature, it deposits a portion of its carbon, the equivalents of hydrogen become equal, and a rich gas is formed; but this, getting still hotter, deposits more carbon; the hydrogen is now in excess, the gas is poor and gives little light; the heat still increasing, the affinity between the hydrogen and carbon is entirely disrupted, the remaining carbon is deposited, and pure hydrogen given off. Certainly all this can be effected artificially; and that it is so to a large extent in gas-making, is evident from the thick lining of almost pure carbon which soon forms in the interior of gas retorts, and which must proceed from the decomposition of the gas by the red-hot surface—must be deposited from it, in fact. Still there are, probably, three products at least of the decomposition of a liquid carbo-hydrogen: solid carbon, a gaseous product containing much hydrogen, and a solid hydro-

carbon having much carbon, the elements being divided amongst each other. When naphtha vapor is passed over red-hot quartz, it deposits carbon, gives off olefiant gas and light carbide of hydrogen, and forms a crystalline compound, naphthalin. With these facts, is it not reasonable to conclude, that there is a temperature at which, in the process of decomposition, olefiant gas and volatile hydrocarbon should be formed, and which yet should be unable to decompose these into compounds poorer in carbon, the intensity of decomposition being proportionate to that of the heat? The Editor agrees with LEIGH in thinking there cannot be a doubt that there is such a temperature, but it must be far below that at present employed for the manufacture of gas. Let the present system of gas-making be examined, says LEIGH, and the true source of the hydrogen and carbonic oxide, so invariably found in gas, and constituting so large a portion of its bulk, will be seen. It may be premised, that when carbonic acid is passed over red-hot coke, it is resolved into carbonic oxide, by taking up an additional equivalent of carbon.

When compact masses of coal are thrown in heaps, of a hundredweight and a half, into retorts heated to a bright redness, as is now done, they are exposed to two very different conditions: the surface of the mass, the exterior, in contact with the intensely hot retort, is instantly decomposed and charred; hydrocarbons, as olefiant gas, *et cetera*, are eliminated, which also, at this temperature, are partly decomposed and converted into light carbide of hydrogen and pure hydrogen, with deposition of carbon, which, with some undecomposed olefiant gas and volatile hydrocarbons, pass off from the retort. The interior of the mass, on the other hand, is for some time exposed to a very moderate heat, and a simple distillation is accomplished; those compounds that are formed at a comparatively low temperature, the heavy hydrocarbons, which would ordinarily be in a liquid state, are eliminated; a portion, rising into vapor as it reaches the hotter surface, passes off with the gases formed, and condenses again when it has left the retort in the form of tar; but that portion of the vapor which, in its passage, comes into contact with the red-hot surface of the exterior of the mass and of the sides of the retort, deposits a portion of its carbon, and is resolved into simple compounds, olefiant gas and volatile hydrocarbons, which themselves partly undergo the change already described. As the heat penetrates to the centre, and a red-hot mass of charred material of considerable thickness comes to surround the decomposing coal within, as happens towards the end of the distillation, the whole of the hydrocarbons, namely, light oils, volatile hydrocarbons, olefiant gas, and even light carbide of hydrogen itself, that are eliminated, are decomposed in passing over such an extent of heated surface, and pure hydrogen is almost alone evolved. The carbonic oxide, which is formed from the union of the oxygen of the coal, and of the air admitted with the carbon of the coal, is also partially decomposed during the whole of the process, but in an opposite direction; not by depositing carbon, but by taking up more, and being converted into carbonic oxide, which is evolved with the gas.

These are the true sources of the hydrogen and carbonic oxide in gas; they are not necessary results of the distillation, but products of the decomposition of the distilled matter. It has been perfectly ascertained by LEIGH and other chemists, that when olefiant gas is passed through a nearly white-hot porcelain tube, it is entirely decomposed, depositing the whole of its carbon, and giving off pure hydrogen.

The greater the heat employed, then, in the process of gas-making, above a certain limit—namely, that requisite for the decomposition of the liquid hydrocarbons—the greater will be the bulk of the gas, and the poorer its quality; the more light carbide of hydrogen, hydrogen, and carbonic oxide it will contain, and the less volatile hydrocarbon and olefiant gas. The analysis of the gas will, therefore, furnish a test of the excellence of the process employed in the manufacture, and a check on the workman, by exhibiting, in the relative amount of hydrogen, and of the illuminating hydrocarbon, whether the heat has been too great. A large quantity of gas may be made from coal, and very badly made. *The mere amount of gas produced is no proof of the excellence of the manufacture.*

Cannel yielding eleven thousand feet of gas per ton, of specific gravity 1.600, would furnish, for every hundred pounds distilled, about—

	Pounds
Gas,	22.25
Tar,	8.50
Ammonia water,	9.50
Coke,	59.75
	100.00

These proportions will vary considerably, but still the numbers will represent a general average of produce. It has been shown above, that considerably more than one-third of the weight of the gas produced is distilled from the cannel in the form of tar, which contains, and is almost entirely composed of, the richest carbo-hydrogen, and very little oxygen; whilst the gas, as it contains only about forty-five per cent. of compounds of carbon and hydrogen by measure, amounting to about half its weight, has really only eleven pounds, or something near that number, of carbo-hydrogen, and of this only about four pounds will be olefiant and richly illuminating gases. So that the tar truly holds as much illuminating matter, or nearly so, as exists in the gas—not twice as much, as would appear from the numbers; for it must be borne in mind, that in the oils composing the tar the carbon exists in much greater proportion than the hydrogen—one of the lightest, benzol, being a compound of carbon, twelve; hydrogen, six—naphthalin and the solid carbides being represented by carbon, twenty; hydrogen, eight; and even higher proportions of carbon. So that, in the decomposition into illuminating gases, much of the weight must be lost in the form of deposited carbon. It will be now tolerably apparent, that in the form of distilled matters nearly one-half of the illuminating portion derivable from coal and cannel is lost to the gas. It is probable that a perfect system of gas-making would produce, from good cannel, a compound containing twenty per cent. of olefiant or other illuminating gases.

MANUFACTURE.—The process followed at the Liverpool gas-works, where the purest gas in the kingdom is produced, will first be cursorily described, so as to give the reader an insight into the manufacture; and, subsequently, the several parts of the apparatus will be treated of fully and separately.

The mode of decomposing the coal is a point of great importance; because, upon its successful results the advantages of gas-lighting, as far as respects economy and profit, principally depend.

The vessels employed for distilling or carbonizing the coal are called retorts, and may be either of cast-iron or fire-clay. Fig. 93 shows a general plan of the gas-works above-mentioned, and Fig. 94 a sectional view, in which A A represents the fire, and B B the retorts.

To introduce the coal into the retort a shovel is used; but in stations having small ones, the coal is placed in a long semicircular iron shovel, or scoop, which, being inverted, spreads it in thin layers, so that every portion of it may be exposed to the action of heat. In order that the required substances may be evolved in sufficient quantities, there must be the requisite amount of caloric; for if a piece of coal is to be extended to two hundred and seventy times its bulk, the heat applied must be equal to the force requisite to produce a separation and expansion of its equivalents.

The heat should be sufficient at the outset to extract the maximum quantity of gas. During the first two or three hours, the greatest proportion of tar is produced. This is accounted for on the principle, that the temperature in the retort is not high enough to maintain the material in a gaseous form, and hence the large amount of tar. If the retort should be too hot, some of the heavy gas will be decomposed, depositing part of its carbon, and forming light carbide of hydrogen; if, on the contrary, it is not sufficiently hot, there will be formed, as just stated, a large proportion of tar, and the gas will be light and of a bad quality. The charge should not be left in too long, as the last portions consist chiefly of hydrogen and carbonic oxide, both of which have a most injurious effect upon the quality of the products. The process requires five, six, or eight hours, according to the nature of the coal and the shape of the retort.

Previous to drawing the charge, the lid is loosened and a light applied; this precaution is necessary to prevent explosion, or what the stoker denominates a *rap*. At large establishments, the retorts are not suffered to lose their heat, but as soon as the incandescent coke has been taken out of them, are immediately replenished with fresh coal, and the operation renewed.

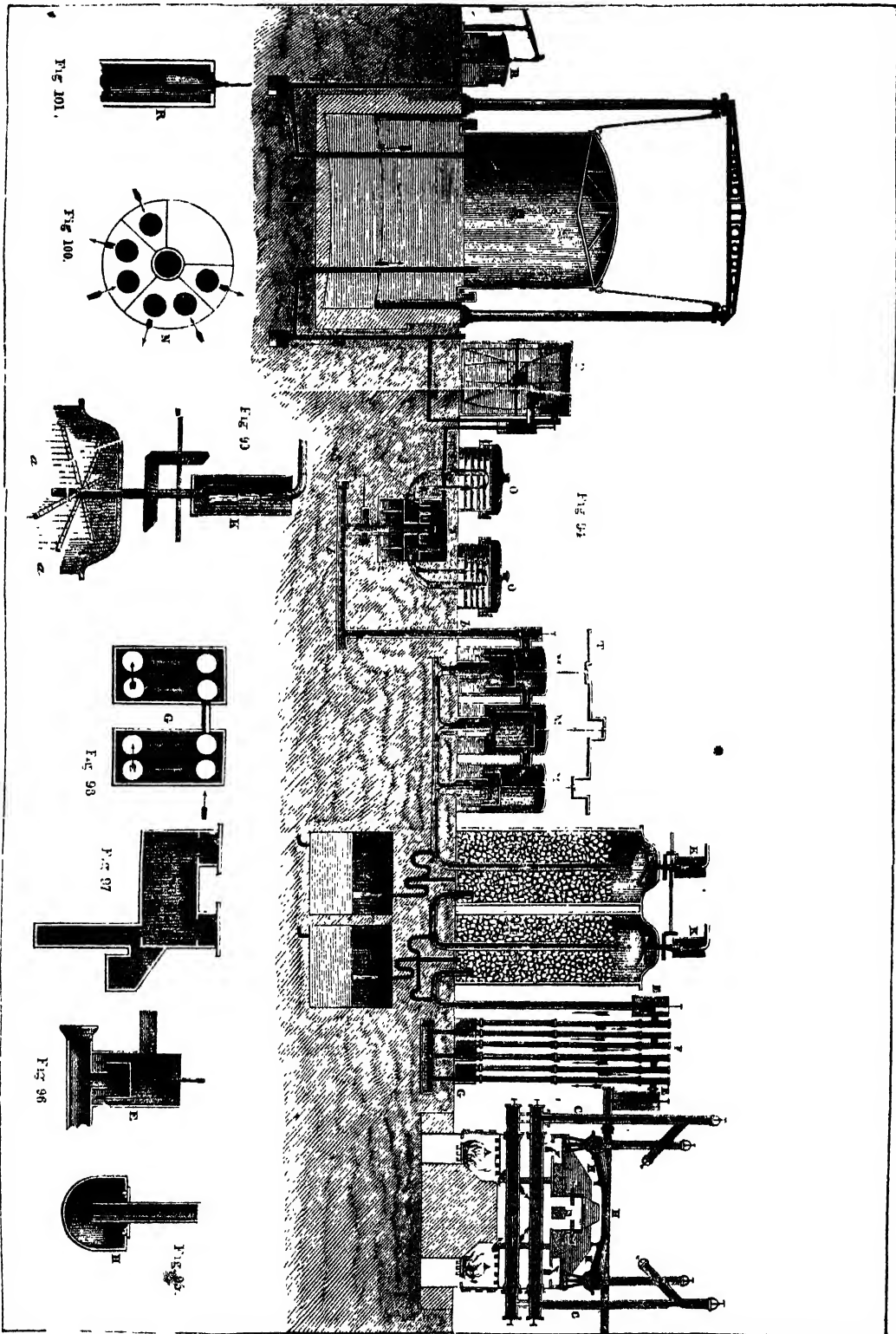
Inasmuch as the coke is withdrawn in a state of redness, the heat required to raise it to that temperature is lost. To remedy this, CROLL introduced the practice of burning the coke as fuel, immediately after its removal, and this plan is said to cause a saving of ten per cent.

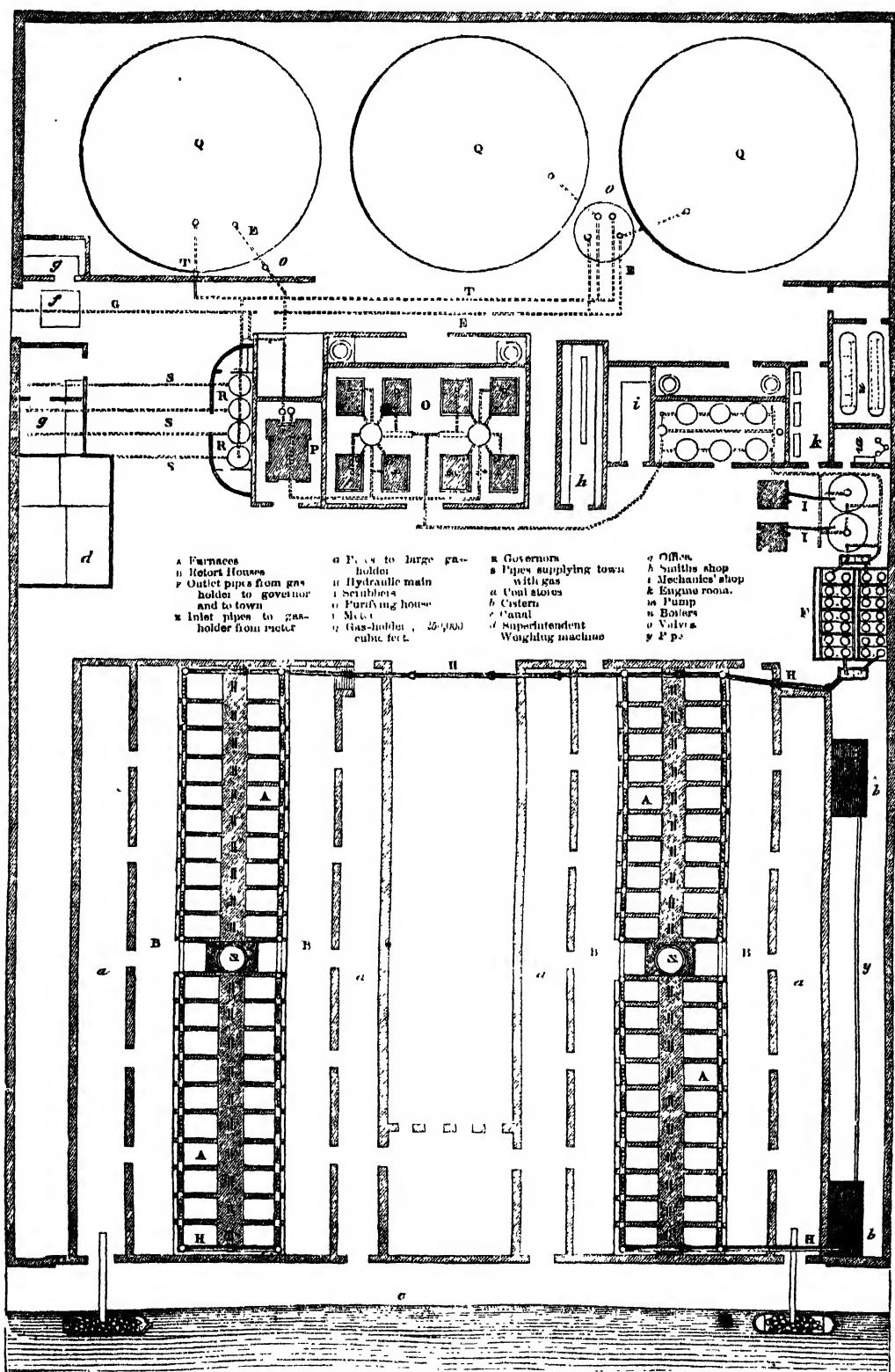
The dense vapors which pass from the retort are conveyed through the ascension pipes, C, Fig. 94, into the hydraulic main, H H, which runs the entire length of the house, and to which all the retorts are connected. Its position must be perfectly horizontal; it is used to cut off the communication between the retorts, when one

or more benches are charging or open. This is shown in Fig. 95. One end of it is perfectly closed by means of a flange, and the other has a similar one. On the top is attached a pipe, through which the gas passes to the condenser. In the outside of this end a piece of iron is placed, so that the water in the main is preserved at a certain height, and cannot sink below the proper level required for the operation. An enlarged view of this is shown at N, Fig. 96. The dip-pipes descend so far into the hydraulic main, D, as to be immersed in the water about three inches; by this means the gas is forced to pass through a quantity of liquid before it can enter the upper part of the main to escape, and becomes partly condensed, and deposits tar and ammonia, but, owing to its superheated state, portions of these products are still retained, and must be separated by further condensation. To effect this, the gas is conveyed into a double set of refrigerating pipes, F F—Fig. 94—closed at the top, and opening into a box, G, at the bottom, a section and plan of which are shown in Figs. 97 and 98. The latter receives two pipes, and constitutes one pair of the series which are united by a short connecting-pipe at the top, as seen in the drawing. The greater the quantity of cold surface the gas is exposed to, the more complete the condensation, and a state of stillness materially aids the deposition of the tar. Thence the gas passes through the scrubbers, I I—two large towers filled with paving-stones—and at the top of which one of the pipes, K K, for conducting water, which is kept continually percolating, is shown in the enlarged view of K—Fig. 99. The condensers and the scrubbers are relieved of their tar and ammonia by the cisterns, L L, which are conveniently placed under ground. The ammonia, being the lighter, floats at the top, and is therefore easily separated from the tar. In the articles AMMONIA and ASPHALT, the purposes to which both products are applied are enumerated. From the scrubbers the gas passes through the exhausters, M M M—a series of apparatus introduced into modern gas-works, for the purpose of drawing off the gas and relieving the pressure in the retorts. They are worked by a shaft, T, connected with the engine.

The gas then enters through a pipe, b b, into the chamber, N, a plan of which is given in Fig. 100. From this it is conducted, as shown by the arrows, through the dry lime purifiers, O O, where it parts with its carbonic acid and sulphide of hydrogen. It is next conveyed to the station-meter, P; thence to the gas-holder, Q; then into the governor, R, the principle of which is illustrated in Fig. 101; and, lastly, to the main, S, supplying the town with gas.

Whoever enters, says DUM, for the first time into a retort-house cannot fail to be struck with its appearance. The iron roof and floor—the absence of windows, machinery, and work-benches—the curious appearance of the walls, covered over with complicated iron-work—the darkness of the place—the appearance of the men,—all have an aspect of strangeness. But, at intervals of every hour or two, and especially at night, the visitor's attention is suddenly awakened to a startling scene going on within the building. A set of men are seen advancing to one part of the side apparatus; they turn the handles of what appear to be screws; several ex-





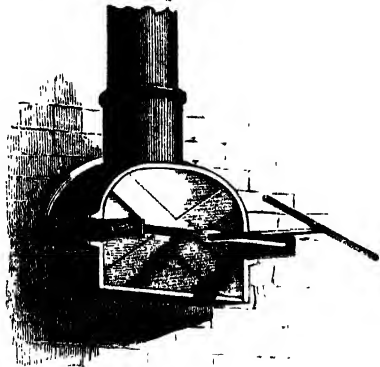
plosive reports are heard, followed by the removal of circular iron doors or covers, about a foot in diameter; a burst of flame then issues from each orifice from which a cover has been taken; and, on going in front of one of these openings, there will be perceived a mass of intensely burning coal, or rather coke, extending back to the depth of six or seven feet. Then will follow the

Fig. 102.



removal, by means of rakes, of all the burning materials from each aperture; then the hissing and steaming consequent on the wetting of the coke by buckets of water; and, lastly, the re-charging of the heated cavity with fresh coals. It is not until after witnessing this series of operations that a stranger can rightly understand the arrangements of such a place. Fig. 102 gives some idea of the retort-house.

Fig. 103.



Retorts.—As the form of the retorts in which the coal is distilled, and the material of which they are composed, are matters of paramount importance, it will

be desirable to enter fully into details with regard to them. They are usually of cast-iron, seven feet long, and one foot in diameter.

TOMLINSON states that, before being used, they are tested by being placed in water, and then forcing air through them; if any flaw exist, it is detected by the air escaping in bubbles. Each retort is generally in two pieces, which are connected by flanges and screws—namely, the *neck* or *mouth-piece*, and the *body* or *hinder part*, which, by constant exposure to the fire, soon wears out, and requires renewal, while the mouth-piece is but little affected. The retort is charged and discharged at the mouth, which is closed by a lid, and fixed by means of a screw and a holdfast, the joint being made tight by a luting of clay, or refuse lime from the purifier. The gases which are generated from the coal escape from the retort by a wide tube, cast into the mouth-piece, and shown in Fig. 103, rising up therefrom. The best form for the body of the retort for obtaining a large quantity of gas in the shortest time, was long a matter of discussion.—*Tomlinson*.

That shape of retort would be best which would bring the whole charge into connection with the red-

Fig. 106.

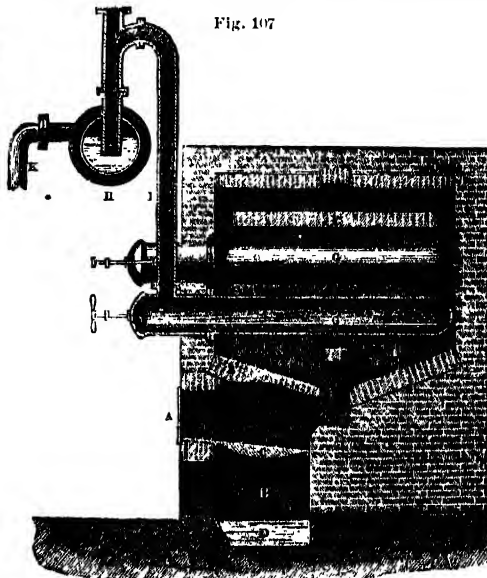
Fig. 105.

Fig. 104.



hot sides. Hence, at the suggestion of PRECHTL, the original circular form of retort—Fig. 104—was soon superseded by the elliptical one—Fig. 105—and this has been improved by bending in the lower surface—Fig. 106. With the same length of 6·5 feet, exposed to the

Fig. 107

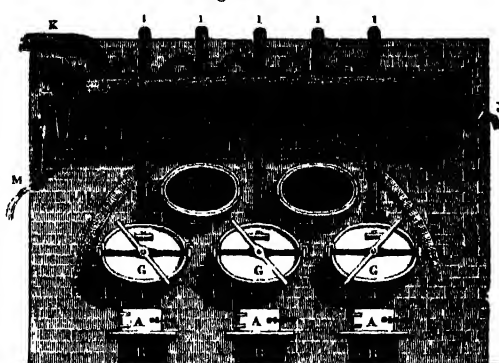


fire, one hundred and fifty pounds of coal, when they only half-fill the retort, will cover, in the round retort, a red-hot surface of ten inches in width; in the oval retort, a surface nearly of twelve inches. The layer

of coal, in the latter retort, is four inches thick, and about one-third nearer to the top of the retort than in the circular form. These advantages, which are self-evident, are strikingly shown in practice, the requisite time for heating being reduced to nearly one-half.—*Knapp.*

Fig. 107 shows the arrangement and position of the retorts, of which there are generally five placed pyramidally in one furnace. Fig 108 is a front view of the same. To the three fires of the furnace, A is the door, C the grate, and B the ash-pit, with a well, D—Fig. 107,

Fig. 108.



for occasionally drying lime-mud; E is one of the three arches which pass transversely over each fire and divide the flame, F is a large arch overspreading the retorts, G G, against which the flame breaks and escapes at the side. The conducting tubes, I I, rise side by side above the furnace, passing behind a large horizontal tube, H, called the hydraulic main, and lastly turning over above it, enter it, dipping down nearly to the bottom. As this main, H, is filled with tar, the mouths of the tubes, I I, are closed, and there is no connection established between the separate retorts. One may, therefore, be opened and charged, without in the least interfering with the process going on in the other. The greatest portion of the tar separates from the gas in H, which latter passes off through K, whilst the former is carried away by the tube, L, curved for the purpose of keeping H half-full, through M, to a tar cistern, which is shown at N, Fig. 94; H can be completely emptied by means of the tap, J.

A very hot flame, mixed with an excess of unconsumed air—oxidizing flame—is unnecessary for the evolution of gas, and deleterious, on account of the rapid destruction of the retorts which it occasions; everything, therefore, depends upon a uniform, steady fire. The destruction of the retorts is incredibly rapid, and dependent upon several circumstances; besides the combustion caused by the hot air of the fire, the sulphur in the coal converts the surface into sulphide of iron, which melts off, and, lastly, the deposit of carbon in the interior, is of no slight importance. This carbon is partly in the form of hair-like deposit, partly stalactitic, from the dropping of tar, but generally occurs as a coating, one or two inches thick, in concentric layers, and combined with iron to form graphite. The specific gravity of these layers increases rapidly from the inner-

most layer to those on the outside, from 1.7 to 2.3. The outermost contain 1.72 per cent. of iron, the inner layers less; sometimes they are so hard, that they will strike fire with steel, and can be polished like glass. Carbon, sulphur, and the oxygen of the air, are, therefore, conjointly destructive of the retort. The retorts suffer most from the air that enters at the door when the fire is poked, and attacks them whilst red-hot. To protect them from this, the stoking-hole is sometimes situated at the back of the furnace, in a continuation of the chimney, when the noxious draft passes away without attacking the retort.

Fire-clay retorts are now extensively used, especially in very large works; and, from all the Editor can learn, they are superior to cast-iron in every respect, as regards duration and the great quantity of gas they are able to produce. One great advantage which they possess over iron retorts, is the facility with which the carbon that accumulates on their interior can be scraped off. Retorts made of this material, which are charged and drawn at both ends, and are therefore termed *through* or *double* retorts, have been lately very largely introduced; their superiority over single or back-to-back retorts consists in the amount of space gained by leaving out the partition walls, and also the thickness of the ends of single ones. In addition to this, when iron retorts are employed, they become so choked up with carbon, that the charge of cannel has to be gradually reduced as the area of the interior of the retorts decreases. In *through* clays this is obviated; and in order to remove the accumulated carbon, it is merely necessary to leave the retort mouths open, thus allowing a current of air to pass through, and the carbon will peel off in flakes if touched with a sharp bar; a portion may also be consumed. An iron retort will afford, according to various authorities, about seven hundred thousand feet of gas, whilst the same length of a through-retort of the same diameter has been known to produce six times that quantity. The amount of fuel required to heat the through-retorts efficiently, is as yet undecided: some engineers give it as their opinion that the amount requisite is the same as is necessary for iron retorts, whilst others affirm that they need a much larger quantity. Should the clay retorts become by any means cracked, a mixture, composed of the following ingredients, is found to be an excellent cement:—

	Per cent
Fire-clay,	42.5
Loam-sand,	42.5
Glass,	10.0
Chloride of sodium, ..	5.0
	100.0

This compound is ground well together with water. The principle of sealing up the gas by a water lute, or hydraulic joint, is, however, the same in both cases, and affords another instance of those beautiful contrivances for using one fluid in the management and manipulation of another, which is much lighter and more elastic.

The Pipes for connecting the Retorts with the Main.—The pipes leading from the retort to the hydraulic main are not fitted in the retort itself, but into a sepa-

rate casting, termed the mouth-piece, which is commonly of the same size as the mouth of the retort, and is secured to it by a flange and bolts. The same kind of mouth-piece is used for clay retorts, which, instead of a flange, are provided with a ring, four inches in thickness and six in breadth, through which holes are cut to receive the bolts for securing the mouth-piece.

A bent pipe passes up from the mouth-piece to the hydraulic main, the straight part secured to it being called the stand-pipe, while the other straight part passing into the main is called the dip-pipe. The part connecting the dip and stand-pipe is named the bridge-pipe, and this part is usually provided with two bonnets, which can be removed when the pipe requires cleaning. The stand and dip-pipes vary in diameter from three to six inches, a very usual size being four inches. There are various modifications in the arrangement of pipes between the retorts and the hydraulic main. In England, the stand-pipe usually passes up to a height of four or five feet above the main, and is fitted at the top with a semicircular bridge, which connects it with the dip-pipe.

The Hydraulic Main.—This is a tube or trunk, II, Fig. 94, usually but not always of cast-iron, extending the entire length of the retort house, and varying from twelve to eighteen inches in diameter, and generally five-eighths to three-fourths of an inch in thickness, when made of cast-iron. Wrought-iron hydraulic mains are now beginning to be used, and will probably altogether supersede cast-iron, on account of their lightness and strength. These are usually made of larger diameter than the cast-iron, and put together in longer lengths. They are formed of three eighths of an inch boiler plate. The ring forming the main is composed of two circular plates, and one flat piece on the top. These plates are made of two breadths, namely, about three and two feet, and about five feet six inches in length. They break joint with each other, by having their line of division alternately on opposite sides of the main, which is constructed in lengths of twenty-three feet, and at each end of this length, there is a flange three inches wide. At the end of each length, and also midway, is a division plate seven inches deep in the centre.

The cast-iron mains are generally of such a length as to reach over two benches, and the joints are made with bolts and nuts, and iron cement, in the usual manner. In old works, the hydraulic main is usually a circular tube; but of late years, D-shaped mains have been frequently employed, generally with the flat side downwards.

The hydraulic main, when first brought into action, is filled to about one-half with water, but the tar contained in the gas which passes into it is deposited, so that the sealing liquid changes its character, and becomes nearly all tar.

The hydraulic main being filled to the above height, the end of the dip-pipe passes through the water to a depth of three or four inches. The gas from the retorts is then conveyed through the dip-pipes, and bubbles up through the water, till it arrives in that part of the main above the surface of the liquid. The hydraulic

main, therefore, is the first receptacle in which the gas is collected, after its separation from the coal.

It perhaps will not be out of place to call attention, in passing, to the simple yet admirable contrivance exhibited in this apparatus, which is partly filled with a dense fluid for the purpose of forming a perfectly airtight and gas-tight chamber, and cutting off all communication from this chamber to the retorts, while the passage of gas from the latter to the former is entirely free and open. Its *modus operandi* will be evident, if it be considered that the extreme lightness of the gas will always cause it to pass upwards through the tar, while, once arrived over its surface, it has no power whatever to displace the tar, and pass backwards. This exquisite contrivance is termed the water-joint, and the hydraulic main constitutes its first application in the gas manufacture. It is by this method that the chemist is enabled to store and confine his gases in the receivers of the pneumatic trough, and thus, by the use of denser fluids, such as water and mercury, to imprison the most volatile forms of gaseous matter in a mode which, for delicacy and subtilty, infinitely excels every scheme of mere mechanical fitting. It will be seen hereafter how largely this valuable principle of sealing up the aeriform fluids by denser ones, through which they can pass in one direction but not in the other, has been applied in the purifier, the gas-holder, and, in fact, in everything connected with the collection, storing, and distribution of the gas. At present, it may be sufficient to point attention to the value of this property, derived from the different densities of fluids, which gives both to the chemist and manufacturer a power over the aeriform bodies, which they could not hope to obtain by any other means.

Each of the pipes thus dipping into the tar of the hydraulic main freely delivers the gas produced in its own retort, and the liquid effectually prevents its return. However numerous may be the pipes entering into it, whether they contain gas or not, and whether the retorts are working or not, it is impossible that any gas delivered above the surface of the tar in the main can escape back.

The length of the dip-pipes should not be less than three feet, and is frequently made as much as five, in order to prevent the tar rising in the dip-pipes connected with the empty retorts as high as the bridge-piece. It is obvious that the pressure of gas from the working retorts will force the tar up a short distance into the empty dip-pipes, but this seldom equals three feet. As the hydraulic main is generally half filled with tar, its diameter must be so regulated that the latter forced up into the empty dip-pipes will not so far diminish the depth in the main as to uncover the ends of the former, because this would simultaneously unseal every one of them, and the gas would immediately escape.

The hydraulic main is sometimes placed in the solid structure of the brick-work over the retorts, but more frequently a little in advance of the ends, in which case it requires to be supported by columns. The hydraulic mains at the Great Central Gas-Works, London, are in the shape of a reversed D, eighteen inches in height and the same in width. There is one on each side of the stack

retorts. They are cast in lengths of nearly ten feet, so as to reach over one bench of retorts, and the joints are placed over the centre of the arches. Their thickness is five-eighths of an inch, with a two and three quarter flange at the ends of each length. The upright pillars to support the mains are hollow columns, seven inches at base, six inches at top, and five-eighths of an inch in thickness. A pillar is placed in the centre of each length, and the opposite pillars are tied together by bars of inch-round iron stretching entirely across the bench of the retorts.

Each length of the hydraulic main is usually provided with a partition, the top of which is level with the surface of the fluid, and the object of which is to keep it to the same height in every part of the main. Of course, where so much depends on the effective sealing-up of the ends of the dip-pipes, every care must be taken to fix the apparatus in a perfectly horizontal position, from end to end. When the hydraulic main is cast-iron, the holes to receive the ends of the dip-pipes are cast in it, and the flanges of the same are secured to the main by nuts and bolts, the joints being made with the usual cement, such as that employed for attaching the mouth-pieces to the retorts. When the main is of wrought-iron, the top is formed by a flat piece, to which the wrought-iron circular part of the main is attached by rivets, and in this flat piece the holes for the dip-pipes are cut by hand. One end of the hydraulic main is closed by a plate having the same section at the outside flange of the main, to which it is bolted and secured by iron cement. A similar plate is also bolted at the other end of the main, but this plate is provided with an orifice usually about half the diameter of the main itself. The lower part of this orifice is immediately above the level of the fluid in the hydraulic main, and the orifice itself corresponds with the exit-pipe, which conveys away the gas to the condenser. The flange of the exit-pipe is bolted on to the perforated end-plate of the main. It is usually provided, soon after leaving this apparatus, with a descending pipe to carry off the tar into the cistern below the condenser. The lower end of this descending pipe must be sealed either by its dipping several feet into the tar of the cistern, or into a small vessel which communicates with the latter. The descending pipe to carry off the tar is not absolutely necessary at this place, because the same office is sometimes performed by the siphon-pipe at the first bottom bend of the condenser.—*Hughes*.

Condenser and Scrubber.—A separate account of these is unnecessary, as the reader will fully understand their use and purpose from the description given of them at page 133, as well as by referring to them on the general section, *FIG. 1*, page 135, and enlarged view, *Fig. 99*.

The Exhauster.—In describing this apparatus, which has been introduced into modern gas-works for the purpose of drawing off the gas and relieving the pressure in the retorts, Mr. HUGHES gives some interesting particulars, which are appended. The modern refinements insisted on with reference to the purity of the gas, all contribute to increase this pressure, as, every time the gas passes through a fluid of greater density

than itself, a resistance is occasioned, which adds to the pressure on the retorts, and this, at length, becomes so great, that means must be resorted to for diminishing it. In the first place, the contrivance of sealing the dip-pipes in the hydraulic main, requires the gas to force its way through several inches of tar before it can escape from the retort, and this is the first obstruction it meets with. In many works where dry lime is used in the purifiers, the gas is conveyed through water in the wash-vessel, where the gas is again resisted, and the pressure of course increased. In the dry lime purifiers and in the scrubbers, it is not considered that any sensible hindrance is opposed to the passage of the gas, but in some works both a washer and a series of wet lime purifiers are used, in which the force imposed becomes considerable, and an exhauster is found almost indispensable. The weight of the gas-holders also adds materially to the pressure in the retorts.

About twelve years ago it was ascertained by Mr. GRAFTON, in the course of some experiments at Cambridge, that the carbonaceous deposit in the retorts was due almost entirely to the pressure on the gas. Previously to this discovery, it was generally considered by the most scientific authorities that the carbon was due to high degrees of heat, and too great an extent of heating surface. In addition to the injury of this deposit to the retorts themselves, causing them to burn out with great rapidity, and the expense of frequently removing it, there is every reason to suspect that some of the very best constituents of the gas, namely, the volatile carbides of hydrogen, are decomposed and condensed in the deposit, and that the gas is thereby much impaired in quality. In addition to this, the pressure causes an increase in the quantity of tar, an effect which never takes place except at the expense of the gas. Mr. GRAFTON conducted his experiments in such a way as to show very practically the truth of the conclusion he had arrived at. By increasing the pressure till it became equal to a column of fourteen inches of water, he produced in a single week a layer of one inch thickness, and at the expiration of two months it had filled up nearly one-fourth of the retort. During this experiment an accumulation weighing ten hundredweight and twenty pounds was produced by the carbonisation of sixty-seven tons of Wall's End coal. Another trial, under entirely opposite conditions, was then made, all pressure being taken off except that arising from half-an-inch dip into the fluid of the hydraulic main. Under these circumstances, when the retort was again worked with the same description of coal for four months, scarcely any deposit had taken place.

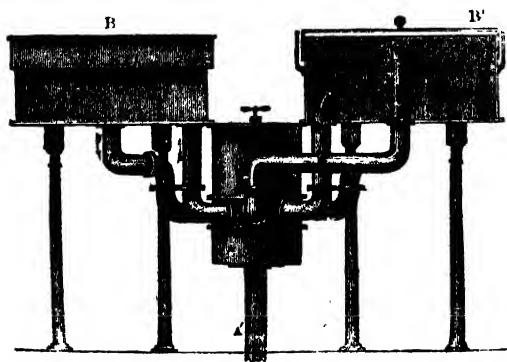
The earliest form of exhauster used was a pump on the principle of the Archimedian screw, which was used for pumping the gas from a higher to a lower point, level with the surface of a small reservoir of water. The screw revolves in an opposite direction to that required for pumping up or raising liquids, and, at each revolution, the upper mouth of the helicoidal canal takes in a certain quantity of gas, after which follows the water. The gas descends along the spiral canal of the screw, in proportion to the rate of revolution in the latter, and having reached the lower extremity of the canal, passes

off by a pipe, with an excess of pressure, measured by the height of the surface of the water above the lower extremity of the screw.

Another kind of extractor, which does not require so rapid a movement as the Archimedian screw, consists of a circular drum with four divisions, formed by curved plates proceeding from the centre to the circumference. The wheel revolves in a cistern filled with water to the height of three-fourths the diameter of the wheel; and each of the chambers, formed by the divisions, carries down below the surface of the water a certain portion of gas, which is delivered out of the drum into a pipe passing off at the level of the centre of the wheel. This pipe opens into a chamber containing water about an inch higher than the upper surface of the pipe, and the difference of level between the water in the cistern and in the chamber which the gas now occupies indicates the difference of the pressure. If the force be not sufficiently reduced by passing the gas through one drum of this kind, it goes on to a second or a third, till the required diminution has been attained.—*Hughes*.

Probably the most improved form of exhauster is that used at the Liverpool works, of which there are two sets, of three each, in operation. Exhausters become indispensable where clay retorts are employed, these being porous in their nature. They necessarily take up some space, but repay the outlay, as the oscillation shown on the inlet pipe does not alter more than half-an-inch, whilst other exhausters are known to vary many inches. Their construction is very simple. A pipe from the scrubbers runs under the three exhauster cylinders, with branches to reach to the height of three feet; at the top of the branch pipe there is a valve, and a holder of sheet-iron fits loosely over this, which has also a valve upon it. The space between the inlet pipe and outer cylinder is filled with water, in which the gas-holder works. When the latter ascends, the gas is drawn through the inlet valve, while that affixed to the gas-holder is closed by pressure from above; on its return the upper valve opens and the lower one closes. Each holder discharges at every revolution of the shaft about eighteen feet, and thus the gas is pumped from the retorts. Each cylinder is connected

Fig 109.



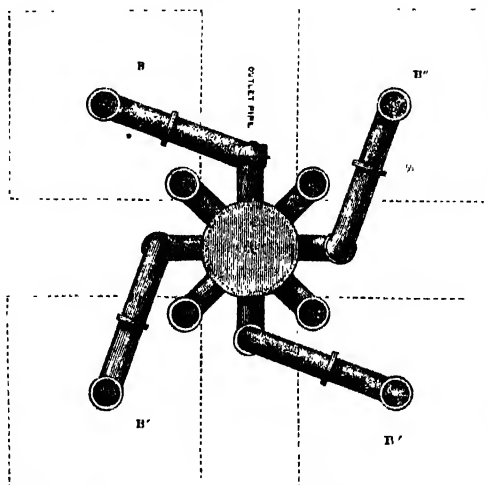
to the other by branches, placed near the top for the purpose of passing the gas through the purifiers, to which it is guided by the centre valve. They are

worked by a shaft, T, connected with a steam-engine, as shown in Fig. 94.

The Centre Valve of Purifiers.—At the majority of works as many as sixteen or even more valves are used for the purpose of guiding the gas into and out of the purifiers. But, by the adoption of one centre valve, as is done in the Liverpool works, the necessity for a number is obviated.

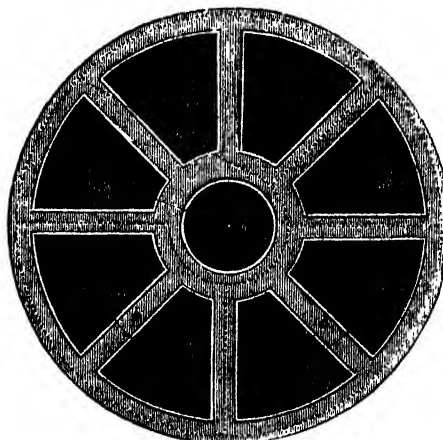
Fig. 109 represents a front view of this most important part of the role of the gas-making apparatus, in which one purifier, B, with which it is connected is shown in elevation, and another, B', in section. Fig. 110

Fig 110



is a plan of the same indicating the position of the four purifiers, B, B', B'', B''', and the inlet and outlet pipes I and from each, by which the gas is made to traverse th

Fig 111



whole. In the general view—Fig. 94—this valve is seen in section, and Fig. 111 shows it more perfectly. In the elevation and plan, Figs. 109, 110, A is the valve, which is so constructed that the gas entering it by the inlet pipe, A', passes through an opening, as shown at a, Fig. 111, and thence flows through a conduit to

the first of three purifiers it has to traverse; the outlet which conducts it to division *b*, enclosed by the dotted line, causing it to pass into the inlet of the second purifier; the same arrangement answers for the outlet of second and inlet of third purifier. From that of the third, it enters through *d* to the division for one pipe, at the top of which there is an opening equal to the area of the pipe, through which the gas enters the upper part of the valve box. From this branches a duct which conveys the gas to the meter, as shown at *p*, Fig. 94. The blank division represented in the plan—Fig. 111—throws out of action the fourth purifier.

Circular pipes would answer all purposes as well as the rectilinear ones shown in the drawings, but a larger box would be required.

LIME PURIFIER.—Of all the substances which have been resorted to for the depuration of gas from sulphur compounds and carbonic acid, lime is the most universal, and the choice does not arise from its cheapness, but more on account of its superior effect in arresting those products which deteriorate illuminating gas.

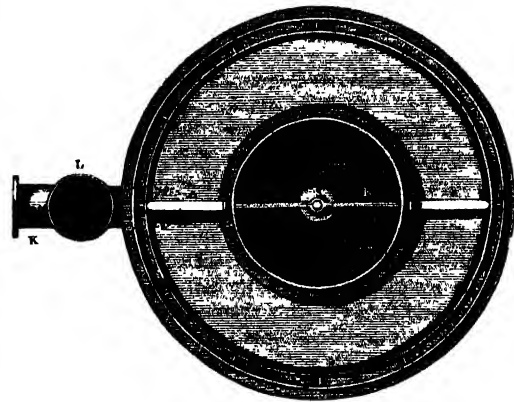
It is employed in two states: in the one case the apparatus is termed the wet lime purifier, from the lime being made into a cream with water, and used in this condition; the other is known as the dry lime purifier, in which quick lime, barely slaked, is resorted to. Their comparative efficiency is matter of dispute among gas-makers.

Both these have an unequal repute for efficiency among gas-makers; but their merits will be best made known to the reader by giving a few brief descriptive sentences upon each.

Wet Lime Purifier.—Fig. 112 is an elevational section of a lime machine, and Fig. 113 a plan through *dd* in Fig. 112. *A* is the inlet pipe, through which the gas passes into the chamber, *n*, which is four feet dia-

—after having overcome the pressure of the column of water in the tank, *plus* the pressure in the gas-holders—will pass, and bubble up through the lime-water.

Fig. 113.

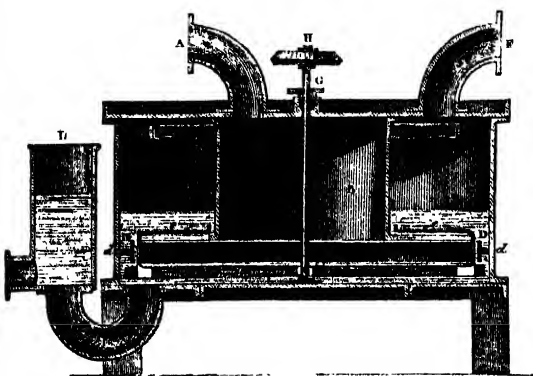


E is an arm made to revolve on the spindle, *s*; the parts *ee* of this arm continue through the aperture and over the ring, serving to keep the lime from settling, or obstructing the passage of the gas. *F* is the outlet for the purified gas. *G* is a stuffing-box, through which the spindle, *s*, passes. *H*, a mitre-wheel, connected to a water-wheel or steam-engine, for turning the spindle. *I* is a pipe, through which the lime-water is drawn off, when it has become saturated with the impurities of the gas. It will be observed, that by this contrivance the water can be completely drained off, by opening a slide-valve bolted to the flange of the pipe, *K*, without suffering the gas to escape along with it, because a column of water will remain in the tube, *I*, equal to the height of the bottom of the tank, measured from the inner radius of the curve of the tube, namely, twelve inches, which is always more than sufficient to overcome the pressure of the gas in the purifier, when the valve on the inlet-pipe, *A*, is closed, which should be done before that at *K* is opened. *L* is a cylindrical vessel, open at the top, for filling the purifier; it also serves to show the quantity of water required; when the machine is at work, the column contained in the vessel will be higher than that in the tank, by the pressure of gas in the gas-holders, usually about three inches.

At the end of 1813, an explosion of a serious nature took place at the Westminster station, owing to a volume of gas escaping from the purifier, which was placed in a building near the retort-house, coming in contact with the flues of the retorts. The windows of several houses in the neighborhood were shattered, and Mr. CLEGG was severely injured. The recurrence of such an event was afterwards guarded against, by drawing the refuse lime-water through a bent pipe, as shown above, always containing sufficient water to seal it.

The lime-water may be mixed in a cistern—having its bottom *above* the level of the water in the purifier when filled, and furnished with an agitator worked by hand—and drawn off by a hose into any of the ma-

Fig. 112.



meter, jointed to the lid of the purifier, and supported upon two cast-iron beams, *c*. On to the bottom flange of this chamber, a circular ring of thin wrought-iron plate is riveted, of such a diameter that its outside rim will be within five inches of the tank of the purifier. *D* is a hoop, supported from the tank by bolts, *d d*, *et cetera*, having its upper edge level with the before-named plate, and its lower edge four or five inches below it. The space left between this hoop and the ring is three-eighths of an inch, through which the gas

chines, care being taken to keep the mixture well agitated while passing. The proportions are one measure of paste-lime to three of water; that is, to every five bushels of paste-lime about one hundred and twenty gallons of water must be added. The size of the lime machines ought to be so regulated, that they will contain sufficient lime-water to purify the quantity of gas made in twenty-four hours, without having occasion to fill them higher than the water-line shown in the engraving.

Four lime machines are necessary, two being in action and two out, alternately. When that machine is spent through which the gas first passes, shut it off, and open a third, leaving the second to perform the duties of the first, and so on. The following extract from Mr. CLEGG's journal expresses his opinion on the construction and use of lime machines:—

The grand principle in the construction of a lime-water purifier, is to divide the gas as minutely as possible, at the same time avoiding unnecessary pressure. If the machine be well constructed, seven or eight inches pressure in the machine is quite sufficient. Two sets are necessary, in order to have a pair clean and ready for immediate use. The practice of working the contents of the vessel over again, by passing them from one to another, is mistaken economy.

The work performed by a lime-water purifier is generally computed by its contents in gallons, and the head of water or pressure opposed to the passage of the gas through it. Taking the latter at a constant quantity of eight inches, the computation is easy. Four thousand five hundred cubic inches of hydrate of lime—which, as has been before stated, is the quantity produced by reducing one bushel, or two thousand one hundred and fifty cubic inches of quicklime—mixed with forty-eight gallons of water, will purify ten thousand cubic feet of gas, if properly applied.

Notwithstanding, however, that the quantity of lime required may be well known, it is necessary to test the gas in its progress through the various purifiers. In some cases it is advisable to use the test every twelve hours, or oftener, in districts, for instance, where coal is of inferior and various qualities. Every morning, as soon as the superintendent arrives at the works, he ought to test the action of his purifiers, more especially if he has received a fresh supply of coal or lime. It is necessary only to drop a piece of paper into the plumbous solution, and hold it to the escape-hole of the purifier. The slightest coloration indicates impurity.

Dry lime purifier consists of a square iron box—two are shown at o o, Fig. 94—six feet long by five feet wide, and three deep. The inlet pipe is eight inches inside diameter, and enters at the bottom of the purifier. A few inches above its mouth is fixed a plate about two feet square, which serves the purpose of distributing the gas and preventing any of the lime falling into the inlet pipe. The purifier contains three trays or sieves placed six or eight inches apart, and resting on snuggs cast on the inside of the purifier: each tier contains four trays, each tray being about two feet eight inches by two feet four inches, so that one purifier contains in all twelve trays or sieves, the bottom of each being composed of round rods, five-tenths of an inch diameter, placed about half an inch apart. The top of

the purifier is an inverted box, six feet by five, and with sides and ends ten inches deep, fitting into a water lute twelve inches deep, so that the gas is enclosed by a seal of at least ten inches in depth of water; the outlet pipe passing out of the lid of the purifier is eight inches inside diameter, and is made in the form of a semicircle, the inside diameter of which is two feet; the other end of the semicircle joins another pipe that is fixed. Each end of the semicircle outlet pipe dips into an annular space containing ten or twelve inches depth of water, so as to form a water seal similar to that described for the cover of the purifier. These water joints greatly facilitate the removal of the semicircular pipe and the cover of the purifier whenever required for the purpose of cleaning out or otherwise, without breaking any solid joint or doing injury to any part of the machine. Mr. CLEGG states that two bushels of the hydrate of lime will spread over a surface of sieve equal to twenty-five square feet, with a depth of two and a half inches, which, in practice, is found about the best thickness; and that this quantity, which is equal to one bushel of quick-lime, will, in some places, purify ten thousand cubic feet of gas, while in other places double the quantity of lime will be required.

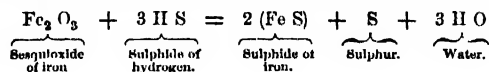
In most of the French gas-works the hydrate of lime is placed upon beds of moss, which are first spread on the trays, or the latter contain alternately a layer of moss and one of lime. The use of the moss is to subdivide the gas into the thinnest possible sheets and streams, so that every particle of it may be brought into contact with the lime.

The purifiers generally used in the French gas-works are from three to four and a half feet in depth, and they are generally made circular, from four to eight feet in diameter, according to the size of the works; in these are placed three or four trays, which contain layers of lime and moss. When the lime is spread upon moss, it is usual to employ rather less than a bushel of lime per square yard of purifier. In most of the French gas-works the quantity of lime used for purification is at the rate of two and a half bushels per ton of coal, which yield, on an average, less than seven thousand cubic feet of gas per ton. The usual calculations with them is, that a purifier with an area of one square metre, or ten and three-quarters feet, is required for every ten hectolitres—two thousand eight hundred pounds—of coal distilled. This proportion is nearly at the rate of one square yard of purifier for each ton of coal distilled. The calculation is made on the quantity of coal distilled in twenty-four hours, this being the interval at which the lime in the purifiers requires to be renewed. It is also made on the supposition that the purifiers contain three layers of lime, so that the proportion becomes three square yards of screen containing lime for every ton of coal distilled in twenty-four hours. The cover of the purifier is made of light boiler plate, provided with a border or rim, which dips into a ring surrounding the purifier, and filled with water, so as to make a perfectly hydraulic joint. The cover is also fitted with handles, by means of which it can be removed when the lime requires to be renewed.

The lime removes from the gas carbonic acid about two per cent., and sulphide of hydrogen about one per

cent. If the gas be properly purified, a paper dropped in a solution of acetate of lead, and held in the gas, will turn black if sulphide of hydrogen be present; if the gas be passed through lime-water, a milkiness will be produced with carbonic acid.

The dry lime purifier is generally preferred as being more handy, less noxious, and offering but little resistance to the gas, *et cetera*. Sesquioxide of iron has lately been introduced into the trays of the dry lime purifier. It ought to answer well, removing the sulphide of hydrogen completely in the following manner:



The resulting sulphide of iron would be of value to the manufacturer of sulphuric acid.

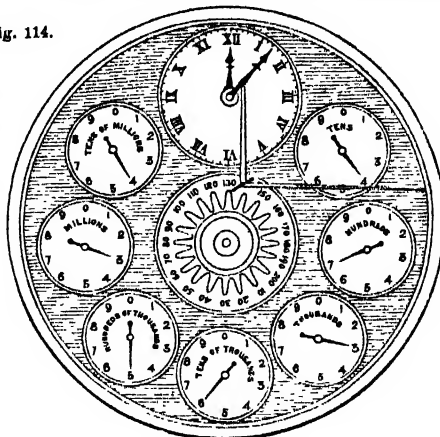
Station Meter, or Measurer, is used for the purpose of ascertaining the quantity of gas produced from the coal; likewise as a check upon the men's work; and also for comparing the gas sold through the consumer's meter with that delivered from the works. The principle upon which it is constructed is as follows:—The part of the meter by which the gas is measured is called the drum, shown at P, Fig. 94; it is a cylindrical vessel, supported at the front and back by an axis, and divided into four separate compartments. These are so contrived, that whilst the gas is entering on one side through the inlet-pipe, it is passing out at the same time from another compartment at the opposite end, and, in its attempt to escape through the water, imparts a rotatory motion to the drum proportioned to its capacity and the quantity of gas allowed to pass through in a given time. The primary cause of this motion is the impulse communicated to the gas from the retort, technically called pressure. The action of the meter depends on its being filled to a certain height with water, over the surface of which the gas is transmitted; the use of the water is to close the aperture through which the gas enters the drum, and it also gives the latter a steadier motion.

At the front of the meter a series of wheels are worked by a shaft communicating with the axis of the drum, which, by means of the index, are registered in cubic feet—from ten to ten millions feet of gas manufactured during any period. The station meter employed at Athol Street, Liverpool, is constructed to register seventy thousand cubic feet per hour—one revolution of the drum will pass about six hundred and fifty. It is the largest of the kind ever made. Fig. 114 is a front view of it. On the face is a *tell-tale*, which serves the purpose of pointing out every irregularity in the production of gas during the twenty-four hours.

The following accurate description is given by TOMLINSON:—In the centre of the *dial-field*—Fig. 114—is fixed a circular plate connected with a train of wheel-work, set in motion by an enclosed drum, through which the gas passes, indicating tens of thousands, hundreds of thousands, millions, and tens of millions of cubic feet of gas. Upon this round plate is fixed a disc of paper, divided into twenty-four parts, with subdivisions. Suppose the meter to register three hundred thousand cubic feet in twenty-four

hours, and the plate to be connected by wheels in the ratio of three to one to that index, which marks one

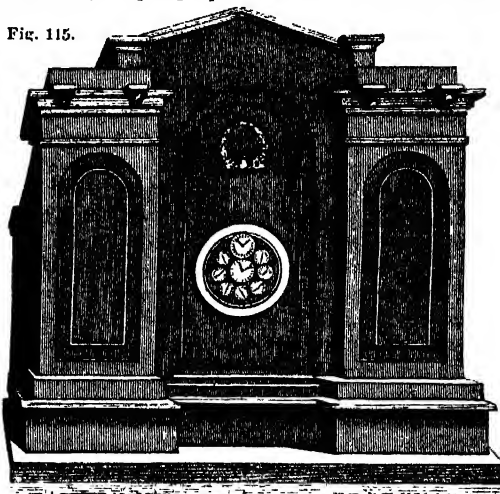
Fig. 114.



hundred thousand in one revolution; it is evident that the distance travelled by one of the twenty-four divisions of the plate from a certain fixed point, will indicate the quantity of gas made in one hour, or $\frac{300,000}{24}$

= twelve thousand five hundred cubic feet. Above this divided disc is a timepiece, to the minute-hand of which is attached a detent, furnished with a pencil, pressing by a spring upon the disc. As the minute-

Fig. 115.



hand of the timepiece revolves, the pencil, by means of a guide fixed to the meter-case, is regulated, so that in the first half-hour it will make a vertical line upon the paper, in length equal to the diameter of the circle formed by the minute-hand, measured from the centre to the point at which the detent is fixed; in the second half-hour the line will be retraced by the hand rising again. This arrangement supposes the divided disc to be stationary; but, as it is made to revolve on an axis, which is also the axis of the internal drum, set in motion by the gas, the pencil will make a series of curved lines, meeting the divided circle of the disc every hour, and the distance travelled from point to point will mark the number of cubic feet of gas made during every hour

of the twenty-four. If the production of gas is regular, the figures formed by the pencil will be so also; if, on the contrary, any neglect has occurred, the irregularity of the figure will detect it, and point out the hour and the amount of difference; because, if the speed of the revolving disc be decreased, the figure formed will approach nearer to the straight line; if increased, the points of intersection upon the divided circle will be further apart. The case of the station-meter is usually greatly ornamented, and bears an appropriate inscription.—*Tomlinson.*

Gas-Holder.—The next subject for consideration is the gas-holders, or vessels in which the gas is stored ready for delivery into the mains, which distribute it throughout the districts to be lighted. These vessels were originally termed gasometers, which name is even sometimes now applied to them; but as they have nothing whatever to do with the measurement of gas, but are merely vessels of capacity, the simple name of gas-holder appears more expressive and appropriate.

The earliest gas-holders were made in the form of cubes or parallelopipeds; but there were disadvantages in this shape, independently of the waste of material required to construct them of this form, as compared with that for a circular one of the same capacity. The corners and angles of the square figures were also found to need bracing, and other precautions were necessary, in order to render the resistance uniform. Wooden tanks were also at one time made for the lifting part of the gas-holder to work in, but this was at a time when they scarcely exceeded in size some of the large vats or backs in use at the great porter breweries. The construction of these wooden tanks was, in fact, entrusted to the back makers, who used to guarantee the duration of the vessel for some period of time agreed on. They were, in consequence, generally constructed in a substantial manner, but it is evident that the rapid increase which took place in the size of gas-holders required the adoption of a different material than wood. When a deputation from the Royal Society, with Sir JOSEPH BANKS at its head, visited the gas-works of the chartered company in Westminster, about the year 1814, they strongly recommended government to restrict the company from constructing gas-holders exceeding six thousand feet in capacity, to be confined in very strong buildings. When Mr. CLEGG published his work in 1841, he says *gas-holders are now constructed to contain two hundred and fifty thousand feet*. In 1853 all the new gas-holders of the Great Central Gas Consumers' Company contained four hundred and twelve thousand feet, and there is one in Philadelphia one hundred and forty feet in diameter, and seventy feet high, capable of containing more than a million cubic feet.

The modern gas-holder is a cylinder of plate-iron, made of sufficient capacity to contain the maximum quantity of gas produced in twenty-four hours; and in very large works, where several gas-holders are used, the joint capacity of all should be equal to this maximum production. In many gas-works the capacity of all the gas-holders somewhat exceeds the consumption of the longest night, but it is believed this excess in capacity is unnecessary. The cylinder which contains the gas has no bottom. or it may be described as a cylinder inverted

over a cistern of water, both the inlet and outlet pipes having their orifices above the surface of the water, so that the gas is hermetically sealed up within the holder, and can only escape through the outlet pipe. The mode in which gas is stored in the gas-holder bears a very exact analogy to that of collecting and storing pursued by the chemist in the laboratory, where the jar to be filled is inverted over a trough containing water, and the gas admitted into it by a bent pipe passing up through the water. In the chemist's method, however, the jar or gas-holder remains fixed, while the water is displaced by the gas; in the gas manufactory, on the other hand, the water is not displaced, but the gas-holder is raised by the gas flowing in.—*Hughes.*

The Editor deems a further explanation of this apparatus unnecessary. The reader will have a very good idea of the mode in which it is suspended by referring to q, Fig. 94. Mr. ALFRED KING states that the pressure on the gas-holders varies from three to five inches—columns of water—but the distributing pressure, which is regulated by an instrument called a governor, about to be described, alters, according to the elevation of the district supplied, and the hour of the day or night, from four-tenths of an inch to two inches.

The Governor.—This is one of those ingenious self-acting machines which are equally admirable for their efficiency and simplicity. It is placed between the gas-holder and the principal main pipe, in order to regulate the pressure of gas admitted into the latter, and acts quite independently of any irregularity due to the unequal action of the gas-holder, or to other causes. The governor is important in another point of view, namely, where a town has several different stages of elevation, and where, without some contrivance, the pressure of gas passing through the mains would vary very much on each different stage. It has been found by experiment that the pressure in a main varies at the rate of one hundredth of an inch for every foot of rise or fall.

In the case of a district being below the works, a governor is seldom necessary, the works being generally, as a matter of convenience, placed at a tolerably low level; and it is found practically that a district lying even thirty feet below the works may be lighted without the intervention of a governor to increase the pressure, as the diminution due to the difference of level would be only three-tenths of an inch of pressure. But governors are especially necessary in towns, such as Bristol, Bath, Edinburgh, Liverpool, Lincoln, Nottingham, Exeter, and many others which have different stages of elevation; because the gas, as it reaches the higher part of the town, will act with so great a pressure as to produce very serious leakage in the pipes, besides the disadvantage of giving the upper districts an undue proportion of light at the expense of the lower. Separate governors for the regulation of pressure at different stages of elevation are not considered necessary, unless the ground has a rise of about thirty feet; and in order to carry out the principle of uniform pressure to the utmost advantage, there ought to be as many governors as the quotient of the whole elevation in feet divided by thirty. Every gas-work for lighting a town should have at least one governor, to regulate the pressure of gas passing from the gas-holders into the first main. Many towns

in flat situations, which have no elevations much exceeding thirty feet, will require only this one, but in other very hilly towns it would be advantageous to have several smaller governors to regulate the pressure for their different levels.

The governor is merely a miniature single-lift gas-holder—shown at R, Fig. 94—suspended from the centre, and furnished with an inlet and outlet pipe, the former having a conical piston suspended in it—Fig. 101—which regulates the admission of the gas in the reverse ratio of its pressure. The lifting part is usually a cylinder of very thin sheet-iron, about five times the diameter of the inlet pipe, so as to give plenty of room for the two pipes to stand inside, and leave a space above for the gas to occupy in passing through the governor. The tank is made of cast-iron plates, of a circular form, usually somewhat less in depth than the diameter, and with the capacity of about two cubic feet for every ten thousand feet of gas required to be passed through in twenty-four hours. Thus, a tank about five feet four inches diameter, and four feet six inches deep, will be sufficient for a governor to pass three hundred thousand cubic feet of gas in twenty-four hours. The lifting part or invert cylinder, R, is about the same depth, and about four inches less in diameter. The inlet pipe, which may be about twelve inches or less in diameter, is provided with a flange at the base, and is screwed to the bottom of the tank, where it passes up the centre through the water contained in the tank. The top of the inlet pipe is also provided with a flange, on which is screwed an annular casting, which contracts the opening to eight inches. In this inlet pipe is suspended a solid cone of iron, varying from six to fifteen inches in diameter at base, and about two at top. This cone is suspended from and attached to the centre of the roof of the lifting cylinder, R, so that the cylinder and cone rise and fall together. To the centre of the roof, on the outside, is attached a chain passing over a pulley, which sustains, at its other extremity, a weight so adjusted as nearly to balance the weight of the conical piston. It is evident that, when the pressure of gas is very small, the cone descends, and allows a large escape from the top of the inlet pipe; and, on the other hand, when the pressure increases, the cone will rise and contract the openings, so as to cause a diminished quantity of gas to enter. Of course the perfection of this action depends on an accurate adjustment of the weight, and when once this is effected, the regulation of pressure is so perfect as to leave nothing to be desired. The gas, when once admitted into the space above the inlet pipe, finds no impediment to its progress, and passes off by the outlet pipe without further hindrance. The cone is usually made of cast-iron, and is turned true in the lathe. The orifice at the top of the inlet pipe is also bored true, and of a conical form, so as to fit the base of the cone. The regulation of the weight and counterbalancing chain is very simple, and needs no further description.—*Hughes.*

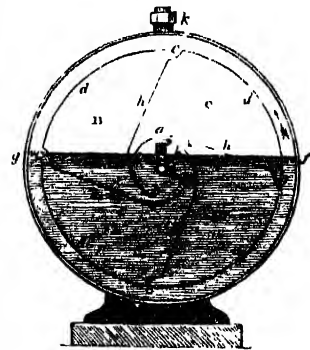
The House-Meter.—This meter, by which the consumer registers his consumption, consists of one hollow drum or cylinder, revolving about a horizontal axis within another hollow drum or cylinder, the inner drum being divided into compartments for measuring the gas,

and revolving in water which occupies the lower part of the outer cylinder to a height above the axis, about which the inner drum revolves. The details of the construction may be varied, but the wet gas meters have this common feature, that the gas is measured in the compartments of a drum, which compartments are occupied successively by gas and water, the drum being made to revolve by the pressure or elastic force of the gas acting on the compartments of the drum in succession. The revolutions of the drum being registered by suitable apparatus, the quantity of gas which has passed through the meter, by so filling the compartments in succession, will be accurately measured.

In Fig. 116, the outer circle represents the outer case or drum of the meter, within which a drum divided into compartments, A, B, C, D, revolves about an horizontal axis, *e*. The gas to be measured is brought into the meter by a pipe passing horizontally in the direction of the axis of the inner and outer cylinder, and turned up at the end, so that its orifice, *a*, may stand above the water level, *f, g*. The four compartments, A, B, C, D, are similar in every respect, each having an inlet, *b*, by which the gas enters the compartment, and an outlet, *c*, by which it passes out of the compartment into the upper part of the outer case, whence it may pass by a pipe, *k*, in any convenient direction.

The gas being admitted into the meter, will pass the inlet, *b*, into the part of the compartment, D, which is just rising out of the water; the gas presses equally on the surface of the water and on the side, *h*, of the compartment, D; the effect of this pressure on the side, *h*, is to cause the inner drum to revolve, whereby the compartment, D, is raised more and more out of the water, and, as it rises, it fills with gas, until it occupies, by the revolution of the drum, the position in space of the compartment *c*, as to which it will be observed that the inlet, *b*, has just dipped below the surface of the water, and the outlet, *c*, is just coming to the surface of the water. The outlet, *c*, having risen above the surface, the gas will escape into the upper portion of the outer case. As the gas passes out of a compartment in the situation of *c*, by the outlet, *c*, water will enter by the inlet, *b*, and as the drum revolves the compartment D having occupied the position in space of C and B, comes into the position A, when it is entirely emptied of gas and filled with water, until, by further revolution of the drum, the compartment having come again into the position of D begins to fill with gas, as already described. That which has been described for one compartment takes place for the other three, and it will be seen that there will always be two compartments discharging their gas into the outer case above the water level, one compartment

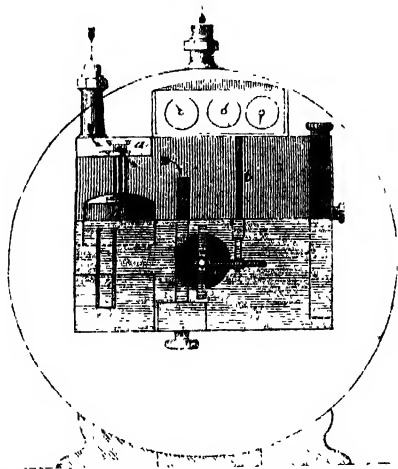
Fig. 116.



filling with gas, and as it fills causing the inner drum to revolve, and one compartment full of water. The motive power causing the inner drum to revolve, is the pressure of the gas in the mains as transmitted from the gas-holder at the gas works, and the quantity of gas will be ascertained from the number of compartments which have filled and emptied, that is, from the number of revolutions of the inner drum, which are registered by a train of wheel work and a dial plate in the usual manner. The gas so measured and passed through the meter is conveyed to the lights by a pipe communicating in any convenient manner with the outer case, and the action of the meter is suspended when the gas does not pass away. It will be observed that the quantity of gas measured will be affected by the height of the water in the meter, the portion of the compartment which is occupied by gas being greater or less, according to the level of the water, whereas the inner drum will revolve whatever the height of the water, within certain limits. If the water rises above the top of the supply pipe, *a*, the entrance of the gas may be stopped altogether, and if it sinks so low that the orifices *b* and *c* are not sealed or closed and opened simultaneously, the gas may pass through the meter without causing the inner drum to revolve. Hence every gas meter is or ought to be adjusted to a certain water level; if the water rise above this level each compartment will measure too little gas, and since the number of revolutions is the same whatever the available space in the compartment for holding gas, the consumer will be defrauded; on the other hand, if the water sink below this level, since the available space in each compartment is larger than was calculated on, the manufacturer will be defrauded. Various causes are in operation to occasion a variation in the water level, and the necessity of preserving it has given rise to several ingenious contrivances for discharging any excess or supplying any deficiency of water.

All this may be further illustrated by Figs. 117, 118,

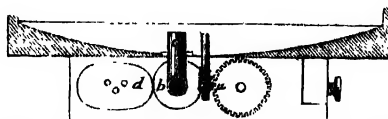
Fig. 117



and 119. In Fig. 117, the direction of the gas is marked by arrows. The box *a*, in which the inlet pipe valve is contained, is soldered tightly, having no communica-

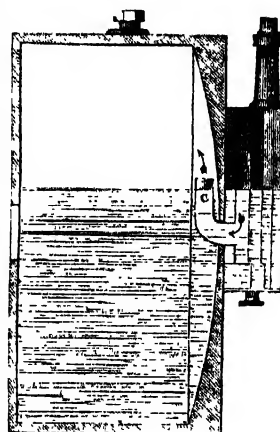
tion with the rest of the case, except through the valve, the position of which is shown by the arrows: *b* is the inlet pipe projecting above the water line, conveying

Fig. 118.



the gas into the meter by the bent arm *c*—Figs. 118 and 119—rising above the water between the convex cover and the inlet hoods. *d* is a float attached to the inlet valve, fixed so that when the water falls below the centre opening the valve will close, and the gas cease to enter the meter. Motion is communicated to the train of wheel-work behind the index from a spiral worm, *u*,—Fig. 118—fixed on to the axis of the drum, working into a wheel, the spindle of which passes through the tube *t*, sealed by dipping under the water contained in the case.

Fig. 119.



There has been much discussion and dissatisfaction in Liverpool of late, with regard to the water meter, parties asserting that although the company had *lowered* the price of gas, still the bills, when they were sent in, were *higher* than they used to be. So many persons came forward and asserted this, that the Editor was applied to by Mr. WHITTY of the Liverpool Journal, to know in what way the above could be accomplished. The following question had to be solved: Is it possible by manufacturing inferior gas to compel the meter to register against the consumer?

In the Editor's opinion it is no matter what kind of gas, insoluble in water, is made, *the registration would be the same*; but if *atmospheric air* was passed into the mains and entered the meter in company with the *coal gas*, it would tell against the consumer, and the *light emitted* would be deteriorated. Mr. WHITTY remarks in reply to the Editor's statements, that experiments performed at the gas works justified them. It appears by introducing one-tenth of common air into the gas-holder charged with gas, that the meter registers ten per cent. or more against the consumer. Some denied that gas so mixed with air would burn, but the results showed that it does, and had no effect visible to the eye, which is an important fact.

The following table, extracted from a paper containing some experiments by Mr. BARLOW, on the comparative value of coals for the manufacture of gas, may be found useful, especially to persons who are compelled to use cannel coal for enriching gas of low illuminating power:—

Name of Coal	Number of experiments, the average of which is taken	Produce of one ton of Coal				Equivalent of one cubic foot of gas in grains sperm.	Consumption of gas per hour to give a light equal to twelve standard candles.	Value of the gas from one ton of coals in pounds of sperm.
		Cubic feet of gas.	Pounds of coke.	Pounds of tar.	Pounds of ammoniacal liquor.			
Boghead cannel,	3	13,334	715	733·3	none.	1109·	1·3	2057
Newcastle cannel,	3	9,833	1426	98·3	60·	606·	2·37	851
Wigan cannel—Ince Hall,	3	10,850	1332	218·3	161·6	465·8	3·09	718
Lochgelly cannel,	2	8,331	1245	225·	340·	439·	3·28	522
Mixture of 7 8ths Lochgelly and 1 8th Boghead,	1	9,055	1200	400·	170·	695·	2·07	899
" 9-10ths Lochgelly and 1-10th Boghead,	2	9,050	1205	335·	290·	600·	2·4	774
" 11-12ths Lochgelly and 1-12th Boghead,	1	9,750	1240	227·	270·	443·	3·25	617
Pelton main,	4	9,500	1540	112·5	112·5	311·	4·7	422
Mixture of 3-4ths Pelton and 1-4th Boghead,	3	12,800	1366	206·6	116·6	553·	2·6	1009

Mr. BARLOW is of opinion that coals which contain more than thirty per cent. of volatile matter, require a higher temperature for their distillation.

As all the volatile matter afforded by coal is not combustible, it does not necessarily follow that the

coal which yields the largest amount of gas is the most valuable, although such is generally the case, as will be seen by the following tables, drawn up by Mr.

SAMUEL HUGHES:—

Description of Coal	Cubic feet of gas per ton of coal	Specific gravity of the gas	Weight of gas in pounds avoirdupois per ton of coal	Authority.
NEWCASTLE COALS.				
English caking coal,	8,000	·420	257	Dr. Fyfe.
Newcastle coal,	11,648	·675	423	Mr. Joseph Hedley.
Pelaw, Newcastle,	11,424	·444	389	"
Pelton, do.,	11,424	·437	382	"
Blenkinsopp, Cathide,	11,200	·521	417	"
Newcastle,	8,500	·412	268	London, 1837.
Wallsend, Newcastle,	12,000	·490	550	{ Quantity made in the revolving web retort —authority, Mr. Clegg.
Pelton,	11,000	·430	363	Author of the Chemistry of Gas-lighting in the <i>Journal of Gas-lighting</i> .
Levenson,	10,800	·425	353	
Washington,	10,000	·430	330	
Pelaw,	11,000	·420	355	
New Pelton,	10,500	·415	335	
Dean's Primrose,	10,500	·430	347	
Garesfield,	10,500	·398	321	
Gosforth,	10,000	·402	308	
West Hartley,	10,500	·420	339	
Hasting's Hartley,	10,300	·421	333	
Blenkinsopp,	9,700	·450	335	Mr. Clegg.
Berwick and Craister's Wallsend,	12,507	·170	449	
Pelaw Main,	12,400	·420	399	
Russell's Wallsend,	12,000	·418	384	
Ellison's Main,	11,200	·416	357	
Felling Main,	11,200	·410	351	
Pearth's Wallsend,	11,147	·410	350	
Dean's Primrose,	11,120	·410	349	
Penton Main,	10,987	·420	337	
Eden Main,	10,400	·400	318	
Heaton Main,	10,400	·410	326	
	9,000	—	—	{ Average production by the Phoenix Gas Company for the year 1848.
PARROT OR CANNEL COALS.				
Yorkshire parrot,	11,000	—	—	Dr. Fyfe.
Wigan cannel,	9,500	{ ·460 to ·520 }	357	"
Scotch parrot,	9,500	·640	466	"
Ramsay's Newcastle cannel,	9,746	{ ·534 to ·580 }	423	"
Lochgelly parrot,	9,123	·667	396	"
Lesmahagow cannel—first experiment,	11,681	·540	483	Mr. Wright.
" " second experiment,	9,878	·650	492	"
Ramsay's Newcastle cannel,	9,016	·604	417	"
" " "	9,333	·598	427	{ John Kay, Manager of Dundee Gas-works.
" " "	9,667	·731	541	{ Dr. Lceson, Dr. Miller, and Mr. G. H. Palmer.
Lesmahagow cannel,	11,312	·737	638	Mr. Joseph Hedley.
Welsh cannel,	11,424	·737	645	"
Wigan cannel,	11,200	·606	520	"
" " "	9,500	·580	422	Liverpool New Gas and Coko Company.
Wemyss cannel,	10,976	·670	563	Mr. Wright.
" " "	10,192	·691	538	"

Description of Coal.	Cubic feet of gas per ton of coal	Specific gravity of the gas.	Weight of gas in pounds avoirdupois per ton of coal	Authority
Wigan canal,	9,408	·478	341	Mr. Wright.
Knightwood canal,	9,720	·590	439	"
Boghead canal,	15,000	·752	866	{ Mr. J. Evans, at Westminster Station of Chartered Gas Company; mean of three experiments.
Lesmahagow,	13,500	·642	666	
"	13,200	·618	627	
Capeldrae canal,	14,400	·577	638	"
Arniston canal,	12,600	·626	606	"
Ramsay canal,	10,300	·548	433	Mr. J. Evans.
Wemyss canal,	14,300	·580	637	"
Kirkness canal,	12,800	·562	552	"
Knightwood canal,	13,200	·550	558	"
Wigan—Ince Hall—canal,	11,400	·528	461	"
Pelton canal,	11,500	·520	459	Mr. Joseph Hedley.
Leverston canal,	11,600	·523	466	"
Washington canal,	10,500	·500	403	"
Wigan canal,	14,453	·640	708	Mr. Clegg.
"	14,267	·610	664	"
Scotch canal,	14,000	·580	622	"
"	13,813	·500	529	"
DERBYSHIRE, WELSH, STAFFORDSHIRE, AND OTHER KINDS OF COAL.				
Derbyshire deep main,	9,400	·424	308	Mr. Wright.
Brymbo two-yard coal,	8,880	·463	315	"
Powell coal—two hundredweight charges every five hours,	10,165	·459	357	"
Powell coal—one and a half hundredweight charges every five hours,	8,250	·470	296	"
Bickerstaff—Liverpool,	11,421	·475	415	Mr. Hedley.
Neath—South Wales,	11,200	·468	401	"
Birmingham Gas Company—lamp coal from West Bromwich,	6,500	·453	226	{ Birmingham Gas Company Parliamen- tary Return.
West Bromwich,	6,500	·455	227	
Macclesfield,	6,720	—	—	—
Stockport,	7,800	·539	322	Parliamentary Return.
Oldham, Watergate, and Wigan canal, mixed, Ormskirk, or Wigan slack,	9,500	·534	388	Manchester Parliamentary Return.
Low-Moor, mixed with two kinds of slack, ..	8,200	·462	290	{ Liverpool Old Company Parliamentary Return.
Leeds coal,	8,000	·420	257	
Canal and common coal mixed, ..	6,500	·530	263	Bradford Parliamentary Return.
Derbyshire soft coal,	8,000	·466	285	Leeds Company Parliamentary Return.
"	7,500	·528	303	Sheffield Company Parliamentary Return.
"	7,000	·448	240	Leicester Parliamentary Return.
"	7,000	·424	227	Derby Parliamentary Return.
"	7,000	—	—	Nottingham Parliamentary Return.
STAFFORDSHIRE.				
South's,	10,933	·398	333	Mr. A. Wright.
Second variety,	10,667	·395	322	"
Third variety,	10,667	·390	318	"
Fourth variety,	9,600	·320	235	"
Forest of Dean,	10,133	·350	271	"
Second variety,	10,133	·360	279	"
WELSH COAL.				
First variety,	10,000	·385	295	"
Second variety,	10,133	·380	295	"

Some practical gas engineers are of opinion that the quantities in the preceding table are larger than are usually obtained in the works. The following table,

by Mr. WRIGHT, in which the results of experiments on the distillation of canal coals are placed in a very practical commercial form, will be found interesting:—

	Name of Coal						
	Lesmahagow canal.		Ramsay's Neweaston canal.	Derbyshire deep main	Wemyss' canal		Wigan canal
	Exp 1 Pounds per ton.	Exp 2. Pounds per ton.	Pounds per ton	Pounds per ton	Exp 1. Pounds per ton.	Exp 2. Pounds per ton.	Pounds per ton.
Coke,	1091·	1064·	1435·	1335·	1124·5	1188·	1326·0
Gas,	463·	483·5	410·	300·	551·4	528·	338·0
Tar,	594·	603·	295·	219·	224·0	197·	250·0
Ammonia and water, ..	4·5	4·5	6·72	179·	—	—	—
Loss,	87·5	85·	93·28	207·	340·1	327·	326·0
	2240·	2210·	2240·	2240·	2240·	2240·	2240·
Cubic feet of gas,	11,681	9,878	9,016	9,400	10,976	10,192	9,408
Specific gravity,	0·540	0·650	0·604	0·424	0·670	0·691	0·478
Illuminating power, gas of specific gravity 0·361, being,	—	2·33	2·	0·8	2·47	—	1·5

The annexed tables, by Dr. FYFE, contain, in addition to the quantities of gas afforded by the coals, much valuable information upon the relative illuminating values of the gases, which he arrived at by the chlorine test. When chlorine is added to coal-gas, it forms with the olefiant gas and the vapors of tar oil—with those constituents, therefore, upon which the illuminat-

ing power depends—a fluid compound, which separates, and the original volume is consequently diminished. The diminution which the volume of the gas suffers when mixed with chlorine is, therefore, in direct proportion to its illuminating power, and to the value of the gas—to the amount of olefiant gas and tar oil vapors—which it contains:—

Coals	Cubic feet of gas per ton	Comparative value of coals per ton by quantity of gas	Specific gravity of gas, air = 1.00	Condensation by chlorine per cent	Durability by jet, five-inch flame	Comparative value of gas by chlorine	Comparative value of gas by durability	Comparative value of gas by chlorine and durability	Comparative value of coals per ton by quantity of gas condensed by chlorine and durability into account
ENGLISH CANNEL:—					M. S.				
Yorkshire,	11,500	1.28	.451	7.66	45*	0.85	0.92	0.78	1.00
SCOTCH CANNELS:—									
Knightwood,	8,960	1.00	.557	.9	48*	1.00	1.00	1.00	1.00
Lochgelly,	9,123	1.01	.567	11.5	65.30	1.66	1.36	1.95	1.11
Marq. Lothian,	10,000	1.11	.556	13*	60*	1.44	1.25	1.80	2.00
Torryburn,	11,200	1.24	.624	13*	57.30	1.44	1.19	1.71	2.13
Moukland,	10,190	1.13	.667	16*	67*	1.77	1.4	2.01	2.29
Arundson,	10,640	1.18	.637	17.5	68.30	1.94	1.41	2.03	2.41
Wemyss,	10,080	1.12	.642	19.5	75*	2.16	1.56	2.21	2.54
Kirkness,	9,620	1.07	.711	20.75	80.18	2.30	1.67	2.40	2.58

This table exhibits the quantity of gas afforded from a ton of each of the coals; the specific gravity of the gas; the amount of condensible matter by chlorine; the durability of the gas when burned by a single jet with a five-inch flame; the comparative value of the gas for affording light, as shown by the chlorine test, by the durability, and by these taken together, which,

when test is had recourse to, is the proper method to follow. It shows also the comparative value of the coals for the purpose of illumination by the combustion of their gases, as proved by the quantity of gas afforded by each, and also by the quantity and quality taken together:—

Coals	Cubic feet of gas per ton	Specific gravity of gas, air = 1.00	Condensation by chlorine, per cent	Durability by jet five-inch flame	Illuminating power, one candle = 1.0 grains per hour	Value of one foot in grains sperm.	Comparative value of one foot in grains sperm.	Value of one ton of coals in pounds of sperm.	Comparative value of coals	Pounds of coke per ton of coal	Fired carbon per cent in coal	Ashes per cent in coal	Pounds of sulphur per ton of coal
ENGLISH CORING:—				M. S.									
Pelton,	9,746	.555	6.5	50.40	3.125	382.2	1*	532*	1*	1,563	—	—	—
ENGLISH CANNEL:—													
Ramsay's Newcastle,	9,692	.625	13.25	60.40	3.33	399.6	1.04	553*	1.04	1,520	—	—	—
Wigan,	12,010	.566	9.9	52.5	3.04	365.4	0.95	627.4	1.17	1,360	55*	7.1	—
SCOTCH CANNEL:—													
Donibristle,	9,923	.593	9*	51.5	7.51	901.2	2.35	1277.5	2.4	1,220	49.22	4.28	8.5
Lesmahagow,	10,176	.669	17*	60*	8.77	1058.8	2.75	1539.5	2.87	1,360	42.44	4*	—
Capeldrae—one,	11,500	.644	18*	65.25	8.312	997.4	2.61	1638.7	3.08	9,999	33.2	7.7	7.7
Capeldrae—two,	9,670	.650	17.8	73.37	10.01	1201.2	3.24	1670.3	3.18	1,256	23.9	24.5	—
Boghead,	15,426	.726	23.37	84.44	10.38	1245.6	3.25	2755.6	4.3	760	9.25	21.7	8*

Having given a full account of the manufacture of coal gas—the Liverpool works, as stated before, being taken as the standard—it will now be desirable to enter upon the fabrication of this compound from other sources, such as oil, resin, *et cetera*; and, in doing so, the Editor will draw largely from the admirable work of Drs. RICHARDSON and RONALDS upon *Fuel*, which has just been published. It contains concise and exact information upon the several heads that will now be discussed.

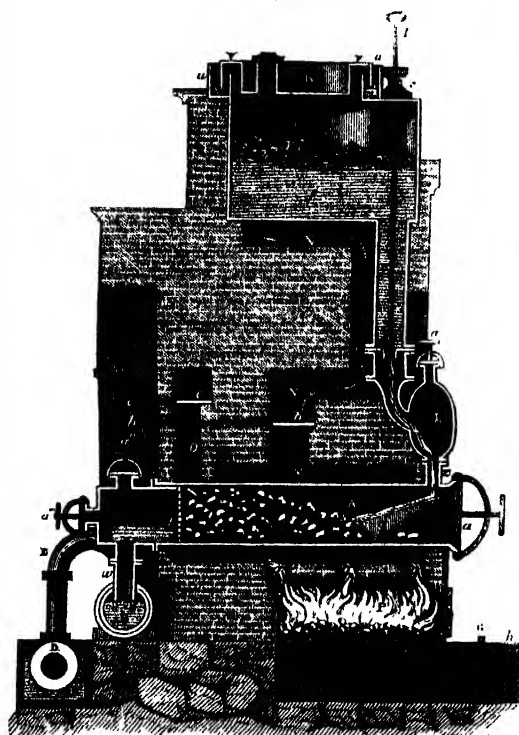
Resin Gas.—Resin could be distilled in the oil-gas apparatus, if it were fluid at common temperatures; but such not being the case, it requires to be liquified

by heat, or some solvent, before it is allowed to pass into the retort. Coal-tar naphtha is often used to dissolve the resin, or the oil which results from its own distillation. When the latter is employed, the flame from the furnace, before escaping into the chimney, is allowed to play upon the reservoir of resin. As the resin melts, it trickles through a sieve into a second division of the vessel, leaving the impurities and the solid portion behind, where it is mixed with an equal part of the resin-oil. Thus a solution which will no longer solidify is obtained, and with it the retort is supplied, as with oil in the former case. When the gas, either from resin or oil, has parted with its condensable

vapors in the coolers, it is in a fit state for consumption, no further purification being required.

According to RONALDS and RICHARDSON, one of the best arrangements of apparatus for making resin gas, and which has stood the test of practice, is that which has been extensively carried out by CHAUSSENOT, and is shown in Fig. 120. The resin is here melted without any additional solvent, and the oil or tar collected and disposed of as a secondary product. The draught to the fire-place, *r*, is regulated through the ash-pit by means of the plate, *g*, which can be moved horizontally backwards and forwards in the groove, *h*. The air traversing from below through the grate and fuel, *rr*, creates a powerful flame, which passing, in the first instance, through the apertures,

Fig. 120



ggg, in the roof, plays round the retort, *A*, in the space, *M*, and then, before reaching the chimney, heats the vessel, *I*, containing the resin, by means of the flue, *NN*. If this vessel requires filling, the fire is shut off from *N* by the damper, *b*, and is allowed free egress at the aperture, *o*, by drawing back the damper, *c*. Both the dampers are worked by iron rings and rods from without. In this apparatus it is not necessary to dissolve the resin in tar-oil, because the vessel, *I*, in which the resin is melted, and the conducting tube, *H*, being con-

stantly surrounded by hot air, no solidification of the melting resin at the bottom, *f*, can take place. Combustible gases are generated by merely melting the resin, which may possibly endanger the whole apparatus. To avoid such contingencies, the edge of the resin cistern, *I*, is furnished with a groove filled with water, *uu*, into which the lid, *K*, dips at *vv*, and is consequently secured by a water-valve. By means of an aperture in the lid, the vapors can be conducted into the chimney or under the grate. The melted resin flows consecutively through *H*, *F*, and *x*, into the retort, *A*. Between *F* and *H* is a plate, *o*, with a funnel-shaped aperture in the middle, in which the conical end of the rod, *d*, is movable. If this is raised through the stuffing-box, *e*, a more abundant supply of melted resin is furnished to the retort; if it is pushed down, the stream diminishes, or the flow ceases entirely. The resin flowing from *x* is carried to that part of the retort containing the coke, by means of the inclined plate, *g*. The coke is prevented falling back in the retort by the grating, *l*, the gas escapes through a descending pipe, *w*, to the tar-cistern, *C*, and from thence through *E* to the coolers, *D*, which are immersed in water in a long trough, *K*. *C* is nearly always filled with tar, that the mouth of *w* may remain immersed; this, therefore, dips into *C*, whilst the gas-pipe, *v*, behind the sectional level in the drawing, only just passes through the material of the main, *C*. Apertures are constructed in several places, at *a*, *a'*, *a''*, and *a'''*, by which the apparatus may be cleaned at intervals; these are firmly closed during the process of distillation, by flat plates of iron firmly screwed on, by means of iron brackets, similar to that used for closing the mouth of the retort *A*. Distillation goes on continually in this apparatus, until the deposition of carbon renders a renewal of the coke necessary.

Resin contains ten equivalents of carbon, seven of hydrogen, and one equivalent of oxygen. Its atomic weight is, therefore, seventy-five. Supposing the whole of the hydrogen to unite with the quantity of carbon required to form olefiant gas of specific gravity nine hundred and seventy six, the utmost that could be produced from an atom of resin would be forty-nine parts out of seventy-five, or about two-thirds of its weight, accompanied by some carbonic oxide and carbonic acid. If any of the hydrogen is evolved uncombined, or in the form of light carbide of hydrogen, a proportionate quantity of carbon must escape conversion into gas, and hence the loss which must always attend the distillation of resin, even supposing that none of it were distilled unchanged, or converted into resin-oil.

Dr. FYFE obtained the following quantities of gas by distilling resin at different temperatures, of which he also ascertained the relative specific gravities and illuminating power:—

Temperature of distillation.	Quantity of gas per pound of resin.	Specific gravity of gas.	Per centage of carbonic acid.	Durability or quantity consumed per hour in jet 1.34 inch diameter, and five inch flame.	In Argand burner consuming five feet per hour, illuminating power was equal to candles.	Resin not converted into gas; fraction of quantity distilled.
	Cubic feet			Cubic feet.	Per cubic foot.	
Heat employed for coal gas, ..	10.0	640	10	1.2	2.45	One half.
Dull red-heat,	6.2	657	6	1.25	2.27	Two thirds.
Somewhat above dull red-heat, ..	8.42	419	8	1.43	—	One-half.
.....	9.	613	—	—	—	One-half.
In White's retort without water-gas, ..	8.8	57	—	1.12	2.	Three-fifths.

He considers, therefore, that the quantity of gas that can be produced from resin in practice will not exceed eight or nine cubic feet per pound, that is, about one thousand cubic feet per hundredweight; that the gas, after being purified, will be of specific gravity not much beyond six hundred; the condensation by chlorine not much beyond eight or nine per cent.; a cubic foot of gas not giving more than the light of from two and a half to three candles.

Hydrocarbon, or Water-gas.—It is well known that water passed in the form of steam over red-hot iron, is decomposed; its hydrogen being liberated in the form of gas mixed with a little carbide of hydrogen from the carbon of the iron, while the metal becomes converted into oxide. If coke or charcoal be substituted for iron in this operation, hydrogen, carbonic oxide, and carbonic acid gases are produced in variable quantities, according to the temperature employed; carbide of hydrogen, according to Dr. FYFE, being only present in very small quantity.

Gas from Animal Matter.—In the distillation of animal matters, bones, flesh, *et cetera*, which has long been practised for the production of bone-charcoal and bone-black, a tar containing DIPPEL's animal oil, and gases, are generated. The illuminating power of the latter has recently attracted the attention of manufacturers. SEGUIN in particular has carried on the process on a large scale, making use of the gases. When the flesh of dead animals, which contains sixty per cent. of water, is employed, the latter must be removed by exsiccation before the material is placed in the retorts, which are kept at a cherry-red heat. The sulphur—a constituent of albumen, fibrin, *et cetera*—is chiefly found in the gas combined with carbon, and the nitrogen of the flesh as carbonate of ammonia. After being properly cooled, the gas is first passed through a solution of chloride of calcium, where carbonate of lime and chloride of ammonium are formed, and thence through pipes containing lumps of sulphur, which condense the bisulphide of carbon to the liquid state. The latter would be converted in the flame into sulphurous acid and carbonic oxide.

Gas from Wood and Turf.—Wood and turf are not well adapted for yielding gas for the purposes of illumination, but where coal cannot be had, or only at a very high price, they may be advantageously resorted to as a means for illumination, as may be testified by many communities at a distance from bituminous coal, which are in the enjoyment of gas-light obtained from one or other of these sources. The illuminating power of the gas liberated from these by distillation, is, it is true, inferior to coal gas; but it may be rendered even superior to the latter, by transmitting it through vessels containing naphtha or oil of turpentine, or retorts which are charged with charcoal kept incandescent by the application of external heat. These facts are entirely of recent discovery. Dr. PETTENKOFER of Munich claims the honor of being the first to prepare gas suitable for illuminating towns and dwellings, *et cetera*, from wood; and his invention is gaining more attention daily in Germany, where the consumption of wood-gas is already very large. The manufacture of gas from wood is stated to offer many facilities

and advantages which are not experienced in the distillation of coal; among these is that of expedition, the gas being freely evolved from the wood, and allowing the charging of the retorts to take place every hour and a half. The tar from the wood distillations is more abundant, and the charcoal is much more valuable than the coke. Further, in coal gas-works the retorts are rapidly worn out, owing to several causes, such as the superior temperature caused by the sulphur in the coal; but it is not so in the manufacture in question, for the heat of distillation is considerably lower, and sulphur is absent. In Munich, where wood gas is used, the usual U-shaped retorts are employed; they are charged with ninety pounds of wood, from which as much gas is obtained as will suffice for two hundred and eighty burners. Immediately on introducing the dried wood into the red-hot retort, gas is evolved, which passes off through an arrangement of pipes, mains, scrubbers, and dry lime purifiers in the usual way. The charcoal, when drawn out, is cooled with wet sand. LIEBIG and STEINHEIL give the illuminating power of this gas as *six*, coal-gas being estimated at *five*.

Oil-Gas.—It appears, at first sight, both inexpedient and superfluous to distil oil for the production of gas, when it is considered that oil can be burnt in lamps without any further preparation, while it loses carbon by deposition in the retorts. Purified lamp oil is consequently never used; but gas can be prepared from impure oils, train-oil, or refuse fat, with as much ease as from the purer kind. The manufacture of oil-gas is, therefore, under certain circumstances, an admirable means of using up such materials for the production of light as could not otherwise be employed, or could only be applied to the lowest uses.

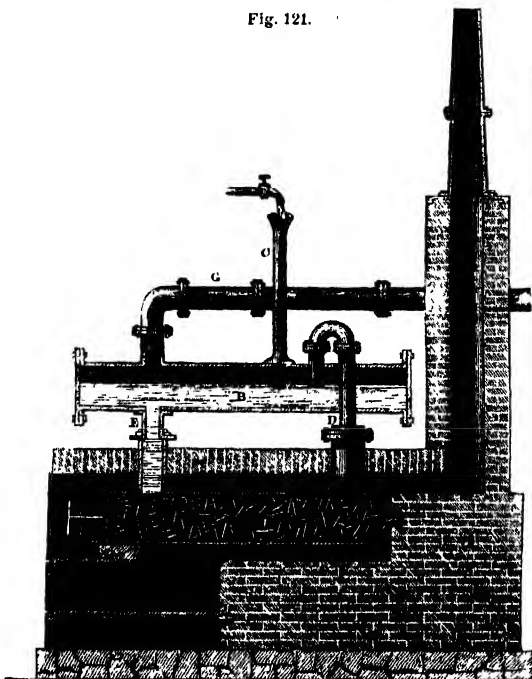
In 1815, Mr. J. TAYLOR obtained a patent in this country for the manufacture of gas from refuse fatty matters, and his plans were carried out at the gas-works at Paris, Liverpool, Bristol, and Hull; but the cost of raw material not being able to compete with that of coal, the oil-gas manufacture has been discontinued in this country.

The experiments of HENRY, which extend also to this part of the subject, show at once the plan that must be adopted upon a large scale. The following account of the results obtained, and the process of the manufacture, is given in KNAPP's *Technology*:—

It appears that the oil-gas is superior to that obtained from coal, as is also shown by its density, and that the produce, dependent chiefly upon the temperature, is of the best quality when obtained at a low red heat. This temperature suffices to convert the oil into gas, but is not sufficiently high to decarbonize the gas to any great extent. The apparatus for obtaining gas by the distillation of oil is represented in Fig. 121. The retort, A, is filled with bricks, or lumps of coke, which very materially increase the red-hot surface, and promote the evolution of gas, shortening the time which the gas already produced has to remain in the red-hot vessel. The second cylinder, B, serves both as reservoir and hydraulic main, A and B being connected in two places, D and E. Oil flows from a large cistern above the apparatus in a constant stream through the

tube c into b, which is thus kept filled up to a certain level. From b, the oil descends through e to a, where it is converted into gas and tar, both of which are volatilized, and return through d to b. The pipe, d, is

Fig. 121.



bent, and its open end delivers just below the fluid level in n, so that the vapors of the decomposed oil must constantly pass through the reservoir of oil, and deposit their tar. The retort, a, is therefore constantly supplied, not only with oil, but with a mixture of oil and tar, in such a manner that all the condensed products return to the retort together with a fresh quantity of oil, until they are completely converted into gas. If the operation be conducted in a long tube, inclined at the hinder part, while the front is kept cool, hardly any tar is produced. The gas which collects above the oil in n passes on through the tube, g. The objections to the use of metallic vessels in distilling coal, are not applicable to the distillation of oils; and cast-iron vessels are, therefore, always employed, and heated over a furnace constructed in the usual manner. According to trustworthy statements, one cubic foot, or about four gallons of oil, produce six hundred to seven hundred cubic feet of gas, which is equivalent to from ninety to ninety-six per cent. of the weight of the oil; the remainder—excepting some unavoidable loss—consists of carbon, which is deposited upon the coke or bricks. According to Dr. FYFE, a gallon of oil seldom yields one hundred cubic feet of gas of good quality, on a large scale. That made at Leith, and in private gas-works at Edinburgh, had a specific gravity of from six hundred and forty to seven hundred and ten, containing matter condensable by chlorine. In this manufacture, about one half only of the oil is converted into gas. The production of oil-gas is a continuous process, and thus differs from the distillation

of coal. The retorts only require opening now and then, for the removal of the deposit of plumbago. Vapors of the same composition and properties are found in oil and coal gas. Thus, according to HESS, all the volatile empyreumatic oils, which occur mixed with each other in the tar from oil, have the same composition per cent. as olefiant gas. In the oil-gas made in England, and submitted to a pressure of twenty or thirty atmospheres, in order to render it portable, FARADAY observed that seven thousand five hundred volumes of gas were converted into one volume of fluid; and among the oily bodies, of which the liquid is composed, and which contain from eighty to ninety per cent. of carbon, this chemist was enabled to study some in an isolated state, as triyl— $C_3 H_3$, ditriyl— $C_2 H_4$ —and a third hydrocarbon— $C_2 H_3$.—Knapp.

Gas from Soap-Water.—A favorable idea of the practical value of chemical knowledge is afforded by the process carried out at the works of HOUZEAU-MUIRON at Rheims, where very good gas and a handsome profit are obtained from a substance which had previously been a source of expense to the manufacturer to get rid of it. This refuse is the soap-water in which woollen stuffs have been freed from fat. Besides the unchanged fat with which the goods are charged as they come from the loom, the soap-water contains a solution of oleate and stearate of soda, and compounds of the same acids with lime in suspended flakes, and, lastly, animal matter extracted from the wool. From all parts of the town the soap-water is collected, and brought to the reservoirs of the works, where three hundredweight at a time are treated with two per cent. of sulphuric acid, or twice as much hydrochloric acid, mixed with an equal quantity of water. After the lapse of twelve or eighteen hours, the water is found to contain GLAUBER'S salt or sulphate of soda in solution, a little gypsum being formed at the same time, while an impure grey fatty matter rises to the surface. This consists of the fatty acids, oil, and animal matter mixed with water, the greater part of which having already been mechanically separated, the remainder is removed by melting the fat in a copper vessel, and ultimately drawing it off into a second boiler containing some sulphuric acid, for clarification. The filtration which follows affords a clear oil, and this gives with crude soda—containing sulphide of sodium—a very tolerable soap, whilst sulphide of iron separates, leaving a black solid residue containing much fat for distillation in the retorts. The process of distillation is similar to that practised with resin; the tar produced the first day is used on the morrow to dissolve and liquify the solid residue. The soap-water is obtained at the rate of ninepence for every thirty gallons.—Knapp.

Hydrocarbon Gas from Boghead Cannel.—The following interesting account of hydrocarbon gas from Boghead cannel, is adapted from an article in the *Journal of Gas-lighting*, from the pen of Dr. FRANKLAND of Manchester:—In the summer of 1851, this excellent chemist made an extensive series of experiments on the manufacture of hydrocarbon gas from cannel coals, in which the results obtained by WHITE'S

process were compared with those yielded by the usual method of gas-making. The experiments were made on a manufacturing scale, the cannels being worked in one hundredweight charges, in diaphragm retorts of the **D** shape, six feet long, one foot six inches high, and one foot wide. The condensing and purifying apparatus was of the ordinary description, and the gas was passed through a station-meter immediately previous to its entrance into the holder, and at a temperature rather below than above that of the atmosphere.

Instead of receiving the whole of the gas in a large holder, and then experimenting upon the total quantity, FRANKLAND preferred, for certain reasons connected with the apparatus then at his disposal, to receive a portion only of the gas in a smaller holder, which was placed close to the meter, and received its supply through a very short three-fourths of an inch pipe from the main entering the meter. This small holder was capable of containing eighty cubic feet, and the flow of

gas into it was continuous throughout the whole process, and accurately regulated by a graduated stopcock, so as to allow the admission of a certain per centage throughout the entire working; for instance, if a ten per cent. sample was being taken, ten feet entered this holder during the time that ninety feet passed through the large meter. He had previously satisfied himself that, by attending to certain precautions mentioned below, this method furnished a perfectly fair sample of the total gas produced.

The results proved, in favor of the hydrocarbon process, a gain of from 45.8 to 290.6 per cent. in quantity of gas, and from 11.2 to 108.6 per cent. in total illuminating power, according to the quality of the cannels used. This gain in the total quantity of light yielded by a given weight of cannels, was also very remarkably corroborated by the analytical estimation of the value of the illuminating hydrocarbons in each gas, as is seen from the following summary:—

	Boghead		Framah-gow.	Methel	Wigan, Incehall	Bulcarra.	Ramsey's Cannel
	1st Exp.	2nd Exp.					
Per centage gain in illuminating power by hydro-carbon process,	88.4	82.4	82.8	108.6	33.9	42.4	11.2
Per centage gain in hydrocarbons expressed in their equivalents of olefiant gas,	83.9	..	85.1	109.2	34.0	..	11.3
Per centage gain in quantity of gas,	188.2	290.6	174.8	176.2	47.9	48.5	45.8

Subsequently, Dr. FYFE also made an extended series of experiments on the same subject; confining his attention, however, to the Boghead cannels, which, he justly remarks, is best fitted for testing the value of the hydrocarbon process. His results differ most widely from FRANKLAND'S, exhibiting invariably a loss of light—sometimes small, at other times enormously great—by the application of the hydrocarbon process.

Dr. FYFE'S experiments were conducted upon a very small scale—small **D**-shaped retorts, two feet six inches long, and nine inches wide, being used, whilst the largest charge of cannels was seven pounds, and even still less quantities were frequently employed. They further differed from FRANKLAND'S trials in the whole of the gas being simultaneously received in two holders, so that the subsequent experiments upon it were conducted upon the total quantity of gas produced; whilst, in Dr. FYFE'S trials, a per centage only of the gas was received and submitted to experiment. To this latter circumstance mainly, Dr. FYFE ascribes the discrepancy in the results.

For some months after the publication of Dr. FYFE'S trials, Dr. FRANKLAND was residing on the Continent; and, for a long period after his return, the want of a suitable apparatus, and the little time at his disposal for such matters, prevented a repetition of the experiments upon Boghead cannels, in order to determine the accuracy or fallacy of former conclusions.

The appearance of another article, however, on the same subject, by Dr. FYFE, in the *Journal of Gas-lighting*, for March 1854, confirmatory of his previous results, determined Dr. FRANKLAND at once to institute new experiments, with an apparatus in which the total quantity of gas could be operated upon.

The apparatus employed consisted of a cannels retort

of the same size as that used in former experiments, surrounded by four water retorts, each of the same length as the cannels retorts, and nine inches in diameter, furnished with a diaphragm in the usual manner. The gas passed from the retorts through the hydraulic tubular condenser, and small wet and dry lime purifiers, to a station-meter, and thence to the holder, where the whole quantity produced in each case was received.

Although two hours were considered amply sufficient for complete intermixture and diffusion of the gases in such a holder, yet an interval of twenty-four hours was in each case allowed to elapse before the gas was submitted to the photometrical experiments. In thus using a large holder, it is indispensable that the gas for the illuminating room should be drawn directly from the water itself, and not from the large outlet-pipe, the unknown contents of which would, in many cases, supply a burner for several hours. This was effected by attaching a flexible tube to an aperture in the crown of the holder, and then conducting the gas to the illuminating room by a half-inch iron pipe. In this manner, a fair sample of the gas in the holder was secured. In all the experiments, the modification of BUNSEN'S photometer, by Messrs. CHURCH and MANN, was employed. The gas was consumed in fish-tail and Winfield burners; and, in every instance, the determination was made when the gas appeared to be burning to the best advantage. The numbers obtained were, as usual, corrected to the one hundred and twenty grain candle standard.

Having previously ascertained that Boghead cannels, when distilled alone, yields considerably higher results in small quantities, and being desirous of placing the cannels in the best possible position for a comparison

only half a hundredweight was used for each experiment, in place of one hundredweight, as employed in previous trials. In making the hydrocarbon Boghead gas, the evolution of water gas was so managed, that the mixture of gases generated throughout the entire working was maintained at a nearly uniform illuminating power. To do this, the generation of water gas must at first be very rapid, and should nearly cease at the end of the second hour. The heat was a good bright red; and, in the trial with Boghead alone, it was slightly higher than in that with Boghead and water.

The following results were obtained:—

I.—BOGHEAD WITHOUT WATER GAS.

Cannel used, Fifty-six pounds.
Gas produced, Three hundred and sixty-four cubic feet.
Time occupied, Two hours and forty-five minutes.
Gas per ton, { Fourteen thousand five hundred and sixty cubic feet.

ILLUMINATING POWER OF GAS.

Two cubic feet per hour, fish-tail No. 1.	Three cubic feet per hour, fish-tail No. 2.	Four cubic feet per hour, fish-tail No. 3.	Five cubic feet per hour, Winfield's burner.
Candles.	Candles.	Candles.	Candles.
14.7	25.5	36.4	48.9

ILLUMINATING POWER OF ONE CUBIC FOOT OF GAS.

Candles.	Candles.	Candles.	Candles.
7.35	8.5	9.1	9.78

Illuminating power of total gas, when burnt at the rate of three cubic feet per hour, = 309.4 sperm candles, each sperm candle burning ten hours, at the rate of one hundred and twenty grains per hour.

II.—BOGHEAD WITH WATER GAS.

Cannel used, Fifty-six pounds.
Gas produced, Nine hundred and four cubic feet.
Time occupied, Two hours and forty-five minutes.
Gas per ton, { Thirty-six thousand one hundred and sixty cubic feet.

ILLUMINATING POWER OF GAS.

Two cubic feet per hour, fish-tail No. 1.	Three cubic feet per hour, fish-tail No. 2.	Four cubic feet per hour, fish-tail No. 3.	Six cubic feet per hour, Winfield's burner.
Candles.	Candles.	Candles.	Candles.
11.1	1.90	26.9	48.1

ILLUMINATING POWER OF ONE CUBIC FOOT OF GAS.

Candles.	Candles.	Candles.	Candles.
5.35	6.33	6.72	8.0

Illuminating power of total gas, when burnt at the rate of three feet per hour, = 572.5 candles. Hence, gain in illuminating power by employment of water gas, per ton, = 10,524 candles; 85.0 per cent. Gain in quantity of gas, = 21,600 cubic feet; 175.9 per cent.

These results, therefore, most satisfactorily confirm those obtained in former experiments, *videlicet*:—

	Per Ton		Per Cent.	
	1st Experiment	2d Experiment	1st Experiment	2d Experiment
Gain in illuminating power by employment of water gas.....	10,028 candles.	9,348 candles.	88.4	82.4
Gain in quantity of gas.....	24,920 cubic feet.	38,480 cubic feet.	188.2	290.6

Thus showing that experiments, in which a certain per centage only of the total gas generated is operated upon, are worthy of full reliance if conducted with the necessary precautions; but, in order that the results may be received with the same confidence, FRANKLAND admits that this method requires more faith in the manipulatory skill of the operator than the other; for, as Dr. FYFE has shown, it is easy to commit very serious errors if the necessary precautions be not attended to. The essentials to accuracy are—first, that the tube supplying the small holder from the main should be as short and narrow as practicable; secondly, the gas should be admitted into the small holder *continuously* throughout the entire working, and not in isolated portions at stated periods; and, thirdly, the sample thus taken should not bear too small a proportion to the total quantity of gas generated. In FRANKLAND's former experiments all these conditions were secured; but in the trial quoted by Dr. FYFE, in which the sample collected in the small holder was thirty-three per cent. worse than it ought to have been, they were disregarded. In Dr. FYFE's experiments, the capacity of the inlet-pipe was one hundred and thirty-two cubic inches, the gas was received in isolated portions at stated periods, and the sample thus collected bore a relation to the total gas of only 1 : 500. In FRANKLAND's experiments, the contents of the inlet-pipe were only eighty-three cubic inches; the sample was collected continuously, and in the three experiments on Boghead cannel, it bore relation to the total gas:—

First Experiment,.....	1 : 8.3
Second Experiment,.....	1 : 23.8
Third Experiment,.....	1 : 32.3

These considerations clearly point to the causes of

the discrepancy observed by Dr. FYFE in his small per centage sample; and as the results of FRANKLAND's second series of experiments, made with all the precaution which Dr. FYFE considers necessary to accuracy, coincide closely, as seen above, with those he already published,—the actual gain of light per ton, ten thousand five hundred and twenty-four sperm candles, being somewhat greater than the mean of the first series, nine thousand six hundred and eighty-eight, and the per centage gain eighty-five,—it now only remains to show the cause of the discordance between Dr. FYFE's experiments and his—the one assigned by Dr. FYFE, viz., the use of a per centage sample, being completely disproved.

In pointing out what FRANKLAND conceives to be the true cause of the discordance, attention will principally be confined to Dr. FYFE's last experiments, in which he used retorts of the customary size; because FRANKLAND is convinced that no results obtained with such a small apparatus, and such minute charges of cannel as those used in his first experiments, can be relied upon for comparison with experiments on a manufacturing scale. He feels also less reluctance in leaving these experiments out of consideration, since Dr. FYFE himself admits, to a certain extent, that they were made upon too small a scale to be depended upon. For the hydrocarbon process especially, retorts of such small *longitudinal* dimensions are peculiarly unfitted; because the amount of carbonic acid generated in the water retort is greatly augmented by diminishing the length of charcoal surface over which the water gas has to travel, and, for the same reason, a great excess of steam is also very liable to pass into the coal retorts, thus damaging the luminiferous constituents there gene-

rated. In addition to this cause of error, the experiments in question must have been much vitiated by the rapid carbonization of the very small quantity of cannel used, nearly the whole of the gas from which would certainly be expelled in thirty minutes—a length of time far too short for the generation of the requisite quantity of water gas from one small retort.

In Dr. FYFE's last experiments, he used two retorts of a large size, one containing the charcoal or coke by which the water was decomposed, the other the coal, of which two hundredweight were used in each charge. Two charges were worked off, both with water gas, and the gaseous products received in a large holder. The average of these trials was twenty-seven thousand cubic feet per ton, yielding light equal to 2830·15 pounds of sperm. Dr. FYFE then compares this result with that which he obtained by working the seven pound charges above alluded to, and thus shows a loss of thirteen per cent. by the hydrocarbon process.

The two principal points, in which the conclusions drawn by Dr. FYFE from these results differ from FRANKLAND's, are—first, his high estimate of the powers of the Boghead cannel distilled alone; and, secondly, the comparatively low results which he obtained by the collateral use of water gas. The first of these points arises, as just mentioned, from reliance being placed upon certain results obtained in small retorts with seven pound charges of cannel, which results differ most widely from those of all other experiments, as also from the previously published report of Dr. FYFE himself.

To determine the influence of small charges in increasing the yield and the illuminating power of the gas from Boghead cannel, FRANKLAND put 2·5 ounces of the same sample as that used in his last experiments in a hand glass tube; it gave 1·88 cubic feet of gas, five feet per hour of which yielded a light equal to 64·5 candles. These numbers are equivalent to fifteen thousand four hundred and eighty-two cubic feet per ton, or 3423·7 pounds of sperm per ton—a result which even exceeds that of Dr. FYFE, and shows how little dependence can be placed in experiments upon small quantities of this cannel.

It is, therefore, greatly to be regretted, that Dr. FYFE did not, at the time of making his last experiment at Leith, try a corresponding one with Boghead cannel alone in the same apparatus, instead of continuing to quote the results of his former trials on the small scale, which he admits to be unworthy of full confidence. Had he done so, FRANKLAND feels assured that he would have removed one cause of discrepancy—*videlicet*, his estimate of the value of Boghead cannel when distilled alone, which, as proved, is far too high.

Dr. FRANKLAND acknowledges himself indebted to Mr. A. WRIGHT and Mr. T. G. BARLOW of London, and to Mr. A. KING of Liverpool, for some very important information on this subject—the first gentleman having tested the value of the Boghead cannel during several weeks' working on a very large scale, and the latter two having made a very extensive series of most careful experiments upon a small scale. In Mr. WRIGHT's experiment, three parts of Newcastle coal—Dean's Primrose—and one part of Boghead can-

nel, were distilled in separate retorts, yielding nine thousand five hundred cubic feet per ton; the mixed gases were burnt in a Number 2 fish-tail burner, 2·5 feet per hour giving light equal to thirteen candles. From this result of the mixed gases, the value of the Boghead was calculated to be 5·44 times that of an equal weight of the Newcastle coal; and therefore, taking the well-known value of Newcastle coal at nine thousand feet per ton—five feet per hour = thirteen candles—it follows that a flame of Boghead gas burning five feet per hour would give a light equal to 57·9 candles, at which rate of consumption the total gas from one ton of Boghead would be equal to 2182·1 pounds of sperm. Mr. KING's result is the average of eleven experiments, each made upon the one-thousandth of a ton; the gas was burnt by a Number 1 fish-tail burner, at rates of consumption varying from 1·38 to 2·04 feet per hour. The value assigned by Mr. BARLOW to Boghead is the average of three experiments, which were also made upon the one-thousandth of a ton of cannel, the gas having been burnt at the rate of from 1·44 to 1·92 feet per hour. If, in the experiments of Mr. KING and Mr. BARLOW, the gases had been burnt at higher rates of consumption, there is no doubt that the equivalent of sperm per ton would have been somewhat higher. In addition to this valuable evidence from gentlemen so intimately acquainted with the subject, there is also the statement of the owners of the cannel, contained in their advertisement, which appears monthly. FRANKLAND considers this statement as good evidence on one side of the question, inasmuch as it is not usual for merchants to underrate the value of the commodities they have to sell. These estimates, along with that contained in Dr. FYFE's printed report to the owners of the coal, are now appended with FRANKLAND's results:—

ESTIMATES OF THE VALUE OF BOGHEAD CANNEL.

Authority	Cubic feet of gas per ton	Gas from one ton, = 16 sperm.
Mr. Wright,.....	11,000	2182·1 pounds.
Mr. Barlow,.....	13,344	2077·0 "
Mr. King,.....	13,549	1993·6 "
Dr. Fyfe,.....	14,800	2283·2 "
Advertisement of proprietors of Boghead cannel,.....	13,500	1967·1 "
Dr. Frankland's 1st experiment,.....	13,240	2387·7 "
Dr. Frankland's 2nd experiment,.....	14,560	2441·1 "

The above are by no means selected; they include all the experiments upon this cannel, with the exception of the subsequent ones by Dr. FYFE, to which allusion has already been made. It will be seen from this statement, that FRANKLAND's results are considerably higher than those of any other experimenter. This is ascribed to the use of a diaphragm retort, and he believes that it is impossible to obtain numbers so high as his in retorts of the ordinary construction. The relation of these numbers to those employed by Dr. FYFE for comparison with his experiments on the hydrocarbon process—namely, Dr. FYFE's results with seven pound charges, 16,093 cubic feet of gas per ton; gas from one ton = 3253·5 pounds sperm—must convince every candid mind that his results are far too high, and cannot fairly be quoted for comparison with any experiments on the hydrocarbon process.

Having thus obtained a basis of experimental results for comparison with those yielded by the same cannell when treated according to the hydrocarbon process, FRANKLAND proceeds to show the gain in illuminating power which that method exhibits, when the experiments upon it by Dr. FYFE and himself are compared with these several results; for Dr. FYFE rightly contends that it is to this test, and not to that of gain in quantity of gas only, that the hydrocarbon process must be submitted.

The comparison which FRANKLAND formerly published, as well as the one previously cited, were founded upon equal consumptions of the respective gases; but Dr. FYFE prefers to burn each gas to the best advantage, with a given burner—generally a Winfield—at high rates of consumption, and then to calculate the value of each cubic foot. By this

method, the comparison may be said to be nearly that of equal light, instead of equal consumpts. FRANKLAND and FYFE agree on this point, and think that the basis of comparison, especially in gases differing much in richness, ought to be that of equal lights and not of equal consumpts. By adopting this plan in the following comparisons, the former has been compelled, in the case of his second experiment, to calculate the hourly consumption of a flame giving a light equal to about fifty candles, as he made no experiment beyond twenty candles. A consumption of ten feet per hour in a Winfield's burner is estimated as being equal to the light of 50·6 candles of one hundred and twenty grains per hour. He does not insist upon the absolute correctness of the gain exhibited by his second experiment, although he believes it to be very near the truth:—

PER CENTAGE GAIN IN ILLUMINATING POWER BY THE HYDROCARBON PROCESS AS APPLIED TO BOGHEAD CANNEL.

Name of Experimenter on Hydrocarbon Process	Comparison with results obtained with Boghead Cannel alone, by				Proprietor of Boghead Cannel	Dr. Frankland's First Experiment	Dr. Frankland's Second Experiment
	Mr. Wright	Mr. King	Dr. Fyfe	Mr. Barlow			
Dr. Fyfe—experiment at Leith gas-works,	Per cent 29·7	Per cent 42·0	Per cent 24·0	Per cent 37·6	Per cent 43·9	Per cent 18·5	Per cent 15·0
Dr. Frankland's first experiment,	89·6	107·5	81·2	101·1	110·3	73·3	69·5
Dr. Frankland's second experiment,	105·6	125·0	96·5	118·1	128·1	87·9	83·8
Dr. Frankland's third experiment,	127·7	149·2	117·6	141·5	152·6	108·1	103·6

These numbers prove, in the most incontestable manner, that there is invariably a very large gain by the employment of the hydrocarbon process, varying with the amount of water-gas used, and with the value at which the gas from Boghead alone is estimated. This gain is even apparent from Dr. FYFE's own experiments, although its smallness, in comparison with that exhibited by FRANKLAND's own trials, must strike every observer of the above table. The cause of this is, however, made clearly apparent when the mode in which Dr. FYFE conducted his is taken into account.

Dr. FRANKLAND has found that one water retort is incapable of generating more than one-half the amount of water-gas requisite for one hundredweight of Boghead cannell; and yet, notwithstanding this caution, Dr. FYFE carbonized two hundredweight of cannell with only one water retort; the water-gas power was, therefore, only one fourth of what it ought to have been, and, as might naturally be expected, the gain was only one-fourth of that which a properly-conducted experiment would yield. The Editor considers that Dr. FRANKLAND has clearly demonstrated that there is a high gain in the total illuminating power obtainable from a given weight of Boghead cannell by the employment of the hydrocarbon process, and that his former estimate of that gain—at from eighty to ninety per cent.—was by no means too high. Since the publication of his first report on hydrocarbon cannell gas, he has had abundant opportunities of witnessing the working of the process; and although he admits that it is more liable to suffer from the carelessness of workmen than the old process, yet his confidence in its merits, and in its ultimate extensive adoption by gas engineers, continues in every respect unshaken.

Illuminating Power of Gases.—The illuminating power of gas, say RICHARDSON and RONALDS, has generally been estimated by the shadow-test, or by BUNSEN's photometer, in conjunction with an experimental meter for accurately measuring the consumption. The standard of comparison used by different experimenters has not always been the same; but a spermaceti candle, consuming one hundred and twenty grains per hour, is now generally adopted.

Illuminating gas must vary in its power of giving light according to the proportion of carbon it contains; but much depends upon the mode of combination in which this element is present, and also upon the manner in which the gas is burned. Thus, carbon, in the form of carbonic acid, is not only useless as a source of light, but actually prejudicial, a very small proportion of carbonic acid in coal-gas reducing the illuminating power to a great extent. Carbon, in the form of carbonic oxide, and as light carbide of hydrogen, is of little or no value as a source of light, these gases burning with a very faint flame. The heavy carbide of hydrogen, as olefiant gas, oil-gas— C_8H_8 —and the vapors of naphtha, many and indeed most of which are condensed by chlorine, bromine, and anhydrous sulphuric acid, are the ingredients of coal-gas to which it owes its illuminating power. Hence the value of gas as an illuminating agent has been frequently estimated since the time of HENRY, by the amount of condensation which it undergoes when mixed with a sufficient quantity of chlorine to absorb these higher compounds of carbon with hydrogen. Dr. FYFE relies most implicitly upon the condensation test by chlorine, in connection with what he terms durability, for an accurate indication of the value of any gas; and he has shown, in a great many

instances, that these two points give a value which agrees very well with carefully-conducted photometrical experiments. By durability, is to be understood the time during which a certain volume of gas will continue to afford a standard amount of light. Bromine is employed by many to replace the chlorine in condensing the heavy carbo-hydrogens, and is, in many respects, more convenient for manipulation. In both cases, the vapors of these substances left after condensation require to be removed from the gaseous mixture by a solution of potassa before the amount of condensation is estimated. Anhydrous sulphuric acid, obtained by warming the Nordhausen acid, is preferred by others for effecting this condensation, a ball of porous coke attached to a platinum wire being saturated with the acid and thrust up into the mixture of gases. The substances condensed from the gas by all these agents appear to be the same; but from what has been stated with reference to the nature of these condensed hydrocarbons from different specimens of coal-gas, the illuminating power of the gas must depend far more upon the chemical constitution, and upon the amount of carbon which they respectively contain, than upon the volumes which they occupy before condensation; and hence, although the test may be a good one, obtained from the same species of coal under like conditions, and containing the same kinds of hydrocarbons, it is not applicable as a means of setting a value upon gases obtained under different circumstances from different species of coal.

The substances condensed by these re-agents are probably similar, if not identical, in composition with those condensed from oil-gas and resin-gas. It has been ascertained, by comparing the density of ordinary Newcastle coal-gas before and after condensation by bromine, that the vapors of the light-giving portions give a specific gravity ranging from 2·8 to 3·3.

The liquid condensed from resin-gas by Mr. COUVERDE yielded six fluids, the nature of which, with the calculated and experimental density of their vapors, are given in the following table:—

No.		Density of Vapor.	
		Calculated.	Found.
1.	C ₄ H ₄	1·763	2·000
2.	C ₆ H ₄	2·385	2·254
3.	C ₈ H ₄	2·806	2·802
4.	C ₇ H ₄	3·230	3·340
5.	C ₈ H ₄	3·660	3·765
6.	C ₂₈ H ₂₂	2·665	2·637

The first of these has a specific gravity about equal to the condensable matter in Wigan cannel and Ramsey's cannel, while the third and fourth resemble that from Pelaw, Pelton, and other Newcastle coals. A more elastic vapor probably remained in the gas from which these substances were condensed, which would have a lower specific gravity, and come to resemble the condensable matters and Lesmahagow cannel-gas. The specific gravity of the condensable matter from these gases may be seen from the annexed table by Mr. EVANS of the Westminster Gas Works, taken from the *Journal of Gas-lighting*:—

Name of Coal	Gas per ton	Condensed per cent by bromine.	Specific gravity of gas	Specific gravity of condensed matter.	Photogenic Power.	
					Actual	By analysis
Boghead,.....	15,000	30·	·752	1·21	37·75	36·3
Lesmahagow, No. 1,.....	13,500	16·	·642	1·64	27·1	26·24
Do., No. 2,.....	13,200	17·	·618	1·43	24·8	24·31
Capeldrae,.....	14,400	16·5	·577	1·29	19·75	21·28
Arniston,.....	13,600	17·	·626	1·40	22·50	23·80
Ramsay,.....	10,300	12·5	·548	1·82	21·40	22·95
Wemyss,.....	14,300	14·5	·580	1·87	24·50	27·11
Kirkness,.....	12,800	10·2	·562	1·55	21·20	19·88
Knightwood,.....	13,200	9·5	·550	2·28	19·00	21·66
Wigan—Ince Hall,.....	11,400	11·5	·528	1·77	20·00	20·35

The following table shows the illuminating value of the gas obtained from Newcastle coal, and may serve as a fair indication of the character of the gas supplied in the metropolis:—

Name of Coal.	Gas per ton	Illuminating power	Specific gravity of gas.	Condensation per cent.
Pelton,.....	11,000	14·0	·430	4·5
Pelton Cannel,.....	11,500	18·5	·521	10·5
Levenson,.....	10,800	12·5	·425	4·
Levenson Cannel,....	11,600	18·	·523	10·
Washington,.....	10,000	14·	·430	5·
Washington Cannel,..	10,500	18·	·500	10·5
Pelaw,.....	11,000	12·75	·420	4·5
New Pelton,.....	10,500	12·	·415	4·75
Dean's Primrose,.....	10,500	13·5	·430	5·
Ponessfield,.....	10,500	11·5	·398	3·75
Gosforth,.....	10,000	12·	·402	4·
West Hartley,.....	10,500	12·5	·420	4·2
Hastings Hartley,....	10,300	12·5	·421	4·3
Blenkinsop,.....	9,700	14·	·450	6·

The only sure method of arriving at the actual

amount of carbon in a gaseous mixture, and at the same time showing the character of the carbonaceous compounds contained in it, is to combine the condensation method with an organic analysis, or by the old plan of combustion with oxygen, as proposed by HENRY, noting the quantity of oxygen consumed, and the amount of carbonic acid produced. Thus, a known volume of coal-gas is mixed with an excess of oxygen and exploded, the amount of carbonic acid produced and of oxygen consumed being ascertained. Another equal volume is then treated with an absorbent, as anhydrous sulphuric acid, and after all the residue is again mixed with oxygen, and exploded; the amount of carbonic acid being again ascertained, and deducted from the quantity obtained by exploding the original gas. The quantity of carbon contained in the condensed portion of the gas being thus ascertained, its value as an illuminating agent may be calculated accordingly. There appear to be some compounds of

carbon and hydrogen in certain coal gases different from light carbide of hydrogen, and which are not condensed by any of the absorbents named, and which, nevertheless, add much to the illuminating power; so that calculations based upon the above method of analysis will prove rather below than above the true value of the gas.

In estimating the value of gases by the photometer, it is absolutely necessary to burn the gas in a great variety of ways—with differently constructed burners, in different quantities, and under varying amounts of pressure—in order to ascertain under what conditions it affords its full value as an illuminating agent. A gas which is very rich in heavy hydrocarbons cannot be burned to advantage with a burner adapted for less rich gas—the apertures require to be smaller, in order to bring more oxygen into contact with each flame; and a poor gas, on the contrary, burned in a manner suitable for rich gas, will not afford its maximum effect, in consequence of too much air being brought into contact with the flame.

If the central ring of an argand burner, consuming oil without smoke at its maximum degree of brightness, be closed so as to exclude the inner current of air from the flame, the brightness is visibly diminished, but, strange as it may appear, the amount of light, as indicated by the photometer, is increased. A greater number of the particles of carbon are rendered luminous before being consumed, by diminishing the supply of air in this manner, and a greater quantity of light diffused, although the light is not so brilliant. By increasing the supply of air, much of the carbon is consumed at once, without taking a solid form in the flame; more heat is then produced, and those particles which are solid in the flame are more intensely heated: quantity of light is then sacrificed to intensity. Gas has little tendency to smoke. It is generally better suited to the production of intensity than quantity of light; and for this reason, in comparing the illuminating power of different gases with each other, it would be better to adopt as a standard the flame of some gaseous mixture of known composition, instead of the spermaceti candle, which is calculated for affording quantity rather than intensity of light.

The more carbon there is contained in gas the heavier it is, and specific gravity has, therefore, been often resorted to, as an indication of the relative value of different gases. If carbonic acid has been completely separated, and no excess of carbonic oxide is present, the specific gravity may furnish an important indication to the manufacturer of the value of gas made under similar circumstances; but it can never replace an analysis in judging of the value of different gases, as the amount of carbonic oxide will vary with the kind of coal used, and the method of conducting the distillation, the specific gravity of which is very nearly equal to that of olefant gas.

Mr. WRIGHT employs a small balloon, capable, when filled, of holding one thousand cubic inches of gas, which is gauged by a ring fitting its largest diameter when full. The weight of the balloon and car being known, and the air expelled, it is filled with gas; weights are then placed in the car until it remains

in equilibrium in the air. The data thus obtained, with corrections for temperature and pressure, afford an approximate means of ascertaining the specific gravity of the gas. Mr. WRIGHT has constructed a table, by simple reference to which, and a knowledge of the weights required to balance the balloon, the specific gravity may be read off for any variations of temperature and pressure. Little reliance is, however, placed by gas engineers upon any test of illuminating power based upon specific gravity, as this is often considerably increased by the presence of carbonic acid and carbonic oxide, which add to the weight without increasing the illuminating power of gas.

CHRISTISON and TURNER observed the following relations between the specific gravity and illuminating power of coal and oil gas:—

Specific gravity.		Relation of Illuminating power.	
Of Coal-gas.	Of Oil-gas.	Of Coal-gas.	Of Oil-gas.
0.659	0.118	100	140
0.578	0.910	100	225
0.605	1.110	100	250
0.407	0.940	100	354
0.429	0.965	100	356
0.508	1.175	100	510
0.529	0.986	100	272 average.

According to a report made by HEDLEY to Parliament, the illuminating power of coal-gas, in twelve principal districts of England, amounts to between 4.408 and 1.645 times that of a tallow candle—six to the pound; but ordinarily about two or three times, when the consumption varies from 2.3 to 1.5 cubic feet per hour, and the specific gravity from 0.58 to 0.412.

With the same burner and gas, the amount of light depends upon the height of the flame, which practically, the pressure being nearly constant, is regulated by the position of the cock, or by varying the size of aperture in the burner. According to CHRISTISON and TURNER, the advantage increases with the height of the flame, but to a limited extent only, and for a simple jet in the following proportion:—

Length of the flame in inches.	Intensity of the light from equal quantities of		Coal-gas		Oil-gas	
	Coal-gas	Oil-gas.	Intensity of the light.	Gas consumed.	Intensity of the light	Gas consumed.
1	—	100	—	—	22.0	33.1
2	100	122	55.6	60.5	63.7	78.5
3	109	159	100.0	101.4	96.5	90.0
4	131	181	150.0	126.3	141.0	118.0
5	150	174	197.8	143.7	178.0	153.0
6	150	—	247.4	182.2	—	—

Thus the point at which further advantage ceases to result on raising the flame of oil-gas is four inches, whilst for coal-gas it is five inches, which in general requires the flames to be higher. The consumption of gas and the intensity of the light increase together, but the latter in a more rapid ratio up to a certain point. This occurs to a still greater extent with argand burners, for which, with the same consumption of gas, these observers found the intensity of the light to be,—

100 282 560 582 582 504
At a height of 0.50 1 2 3 4 5 inches.

According to FYFE'S experiments upon different burners, in which he probably used a better kind of coal-gas, the increase is as follows :—

With twenty-four apertures of one-fortieth of an inch, the diameter of the perforated ring being seven-eighths of an inch,..... 100 121·8 — 188·5 — 236·6 — 235·4

With forty-two apertures of one-fiftieth of an inch, the ring being twenty-one twentieths of an inch in diameter, 100 136·6 — 176·2 — 194·8 — 242·3

Height in inches, ... 1 1·5 1·75 2 2·5 2·75 3 3·5

Lastly, his experiments gave a view of the intensity of the light produced by the same quantity of gas in different burners, when separately compared at the most advantageous height of the flame :—

Burners	Bat's-wing			Argand burners		
	Simple jet	Small	Large	Fish-tail burner	With 24 holes	With 42 holes
Quantity of light from the same amount of gas,)	100 ..	135 ..	164 ..	138 ..	183·5 ..	182·3

According to the observations of HEDLEY, already quoted, which were made in the gas-works at Sheffield, the intensity of the light of a simple four-inch jet is to that of a 3·5 inch argand flame—from fourteen apertures—as 1 : 4·4 to 4·8, the amounts consumed being as 1 : 3 cubic feet, which corresponds to a greater amount of light from the argand burner by from 1·47 to 1·6 for the same quantity of gas. From the general report of the same engineer upon the principal gas-works in England, it is found—in the case of coal-gas—the average specific gravity being 0·476, that a simple jet, four inches in height, consumes on the average one cubic foot per hour.

The superiority of the flat flames over the simple round ones, explains an observation which has been made with regard to the argand burners. When the apertures in it are placed so far apart as to form a circle of distinct jets, the effect is one-third weaker, with the same current of gas, than when the jets—of one-sixth, to one-eighth of an inch—unite into a single flat ring.

The subjoined experiments on the illuminating power of Wigan canal-gas with different burners have been recorded by Mr. ALFRED KING :—

	One-half foot	One foot	One and a half feet	Two feet	Two and a half feet	Three feet	Three and a half feet	Four feet	Four and a half feet	Five feet	Five and a half feet
Single Jet :											
Consumption per hour,.....	·5	1·	—	—	—	—	—	—	—	—	—
One foot = candles,.....	2·15	2·6	—	—	—	—	—	—	—	—	—
One foot = grains of sperm,...	258·3	311·8	—	—	—	—	—	—	—	—	—
Lancashire Fish-tail, No. 0 :											
Consumption per hour,.....	·5	1·	1·5	—	—	—	—	—	—	—	—
One foot = candles,.....	1·78	2·18	1·76	—	—	—	—	—	—	—	—
One foot = grains of sperm,...	214·1	262·5	211·9	—	—	—	—	—	—	—	—
Lancashire Fish tail, No. 1 :											
Consumption per hour,.....	·5	1·	1·5	2·	—	—	—	—	—	—	—
One foot = candles,.....	1·76	2·65	2·55	2·53	—	—	—	—	—	—	—
One foot = grains of sperm,...	211·3	317·9	306·5	303·7	—	—	—	—	—	—	—
Lancashire Fish-tail, No. 2 :											
Consumption per hour,.....	·5	1·	1·5	2·	2·5	3·	—	—	—	—	—
One foot = candles,.....	2·26	3·11	3·5	3·76	3·79	3·66	—	—	—	—	—
One foot = grains of sperm,...	271·2	373·3	420·6	455·7	455·7	439·4	—	—	—	—	—
Lancashire Fish-tail, No. 3 :											
Consumption per hour,.....	·5	1·	1·5	2·	2·5	3·	3·5	—	—	—	—
One foot = candles,.....	2·26	3·48	3·86	4·07	4·07	4·18	4·1	—	—	—	—
One foot = grains of sperm,...	271·2	417·4	463·6	488·3	488·3	501·9	492·8	—	—	—	—
Lancashire Fish-tail, No. 4 :											
Consumption per hour,.....	·5	1·	1·5	2·	2·5	3·	3·5	4·	—	—	—
One foot = candles,.....	2·38	3·49	4·00	4·17	4·74	4·5	4·41	4·3	—	—	—
One foot = grains of sperm,...	285·5	419·5	484·4	500·5	566·7	539·9	530·1	516·6	—	—	—
Bat's Wing :											
Consumption per hour,.....	·5	1·	1·5	2·	2·5	3·	3·5	4·	4·5	5·	—
One foot = candles,.....	1·83	3·01	3·73	4·1	4·12	4·31	4·3	4·46	4·32	4·4	—
One foot = grains of sperm,...	220·	361·6	448·3	492·3	494·8	578·1	516·2	535·1	519·	528·9	—
Sixteen-hole Argand, small holes in ring 0·82 in diameter :											
Consumption per hour,.....	—	1·	1·5	2·	2·5	3·	3·5	4·	4·5	—	—
One foot = candles,.....	—	0·323	1·02	1·9	2·6	3·27	3·72	3·84	3·96	—	—
One foot = grains of sperm,...	—	38·76	123·3	228·7	313·	393·3	446·4	461·7	479·2	—	—
Winfield's twenty-eight hole Argand, registered July 25, 1848, with slightly conical chimney :											
Consumption per hour,.....	—	1·	1·5	2·	2·5	3·	3·5	4·	4·5	—	—
One foot = candles,.....	—	0·344	1·16	2·26	2·71	3·5	3·72	3·84	4·	—	—
One foot = grains of sperm,...	—	41·2	139·1	271·3	325·6	420·5	446·4	461·7	481·	—	—
Winfield's fifty-eight hole Lucet Argand, registered March 20, 1845 :											
Consumption per hour,.....	—	—	1·5	2·	2·5	3·	3·5	4·	4·5	5·	5·5
One foot = candles,.....	—	—	0·318	0·75	1·09	1·57	2·09	2·59	3·07	3·82	4·5
One foot = grains of sperm,...	—	—	38·2	87·5	131·8	188·4	251·1	311·3	368·9	458·8	540·

The following experiments upon the illuminating power of Newcastle cannel-gas, were made by Mr. WRIGHT with the burners used in London for consuming that kind of gas:—

The No. 1 Scotch fish-tail gives a flame fully spread with .85 inch pressure, and when burning at the rate of 1.4 feet per hour, beyond which point it begins to show streaks of blue.

The No. 2 Scotch fish-tail is fully spread with .9 inch pressure, and when burning at the rate of 2.4 feet per hour.

GUISE's burner is an argand with twenty-six holes, the inner diameter of the ring being six-tenths of an inch, and the outer nine-tenths of an inch. It has a metal button, five-tenths of an inch diameter, one inch above the face of the burner. The glass chimney is a

straight cylinder, two inches diameter and six inches long.

With a three-tenth inch pressure, and a consumption of 4.5 feet per hour, the flame becomes irregular, and has a tendency to deliver smoke.

The standard candle used by Mr. WRIGHT consumed one hundred and thirty grains per hour, and for this, to insure a greater regularity of flame, a No. 2 fish-tail, burning .4 feet per hour, was substituted, and found exactly equal to the candle.

In the first of the following tables, the results are multiplied by one hundred and thirty, and divided by one hundred and twenty, so as to reduce them to a standard candle of one hundred and twenty grains per hour, as done by Mr. KING:—

Consumption per hour	One foot.	One and a half foot	Two feet	Two and a half feet	Three feet	Three and a half feet	Four feet	Four and a half feet
<i>Scotch Fish-tail, No. 1:</i>								
One foot = candles,.....	4.875	5.02	—	—	—	—	—	—
One foot = grains of sperma,.....	585.	602.	—	—	—	—	—	—
<i>Scotch Fish-tail, No. 2:</i>								
One foot = candles,.....	5.05	5.77	5.95	5.84	5.53	—	—	—
One foot = grains of sperma,.....	606.	690.	714.	700.	563.	—	—	—
<i>Guise's Argand:</i>								
One foot = candles,.....	—	1.08	1.85	3.12	4.85	4.95	5.77	6.74
One foot = grains of sperma,.....	—	129.	222.	374.	582.	594.	692.	808.

Mr. WRIGHT, however, prefers the subjoined form of quoting the above results:—

SPERMACEETI CANDLES OF ONE HUNDRED AND THIRTY GRAINS PER HOUR.

<i>No. 1, Scotch Fish-tail:</i>															
Gives light =	$\frac{1}{15}$	$\frac{1}{12}$	$\frac{1}{10}$	$\frac{1}{8}$	$\frac{1}{6}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{2}{3}$	$\frac{3}{4}$	$\frac{4}{5}$	$\frac{5}{6}$	$\frac{2}{3}$	$\frac{3}{4}$	candles.
When burning.....	.15	.2	.3	.4	.6	.9	1.3	1.8	2.25	2.7	3.6	4.5	5.4	6.75	feet per hour.
Feet of gas required to produce a light = one candle,....	1.2	.8	.6	.4	.3	.225	.217	.225	—	—	—	—	—	—	
<i>No. 2, Scotch Fish-tail:</i>															
Gives light =	$\frac{1}{15}$	$\frac{1}{12}$	$\frac{1}{10}$	$\frac{1}{8}$	$\frac{1}{6}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{2}{3}$	$\frac{3}{4}$	$\frac{4}{5}$	$\frac{5}{6}$	$\frac{2}{3}$	$\frac{3}{4}$	candles.
When burning.....	.15	.2	.3	.4	.6	.9	1.2	1.5	1.8	2.2	2.6	3.2	3.6	4.5	feet per hour.
Feet of gas required to produce a light = one candle,....	1.2	.8	.6	.4	.3	.225	.2	.1875	.18	.183	.185	.2	—	—	
<i>Guise's Argand:</i>															
Gives light =	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	candles.
When burning.....	1.7	2.1	2.6	3.1	3.5	3.9	4.2	4.5	—	—	—	—	—	—	feet per hour.
Feet of gas required to produce a light = one candle,....	.85	.525	.325	.258	.219	.195	.175	.160	—	—	—	—	—	—	

Mr. BARLOW has recorded some experiments made by him with different burners on gas manufactured from a mixture of Pelton, Felling, and Dean's Primrose, all first-class Newcastle gas coals, the average produce being eight thousand five hundred feet per ton of coal. The burners he used were:—

1st. A Number 3 fish-tail, or union jet.

2nd. A Number 5 bat's-wing.

3rd. A common argand, with fifteen large holes in a ring .85 inch diameter, and a cylindrical chimney-glass 7 inches high.

4th. A Platow's registered argand, with large holes

in a ring .9 inch diameter, with inside and outside cone, and cylindrical chimney-glass 8.5 inches high.

5th. A Bizner's patent Number 3 argand, with twenty-eight medium-sized holes in a ring .75 inch diameter, and cylindrical chimney-glass 8.65 inches high.

6th. A Winfield's registered argand, with fifty-eight medium-sized holes in two rings of twenty-nine holes in each, the mean diameter being one inch, with deflecting button inside and gauze below; bellied chimney-glass eight inches high.

7th. A Leslie's patent argand, with twenty-eight jets

in a ring .95 inch diameter, and chimney-glass 3.5 inches high.

8th. A Guise's registered shadowless argand, with twenty-six large holes in a ring .85 inch diameter, and deflecting button; cylindrical chimney-glass 6.1 inch high, and glass reflecting cone to outside gallery.

On an average of numerous trials the annexed results were obtained:—

SERIES NO. I.

Burner.	Consumption per hour.	Value of one cubic foot in grains of sperm	Standard candles per cubic foot.	Value of eight thousand five hundred feet of gas in pounds of sperm
No. 2,....	4.9	289	2.4	351
No. 3,....	5.5	343	2.85	416
No. 5,....	5.5	374	3.11	447
No. 6,....	5.5	337	2.8	409
No. 8,....	5.5	350	2.91	425

SERIES NO. II.

No. 1,....	5.5	276	2.3	335
No. 2,....	5.0	290	2.41	352
No. 3,....	5.5	341	2.84	414
No. 4,....	5.5	348	2.9	422
No. 5,....	5.5	380	3.16	461
No. 6,....	5.5	335	2.79	406
No. 7,....	4.1	369	3.07	448
No. 8,....	5.5	364	3.03	442

It is quite evident from these experiments that the No. 6, or Dr. Fyfe's Aberdeen argand, required a longer consumpt than 5.5 feet per hour to bring out the full effect of Newcastle coal-gas of the quality used in this case, for, when the consumpt was increased to 6.5 feet per hour, it gave results equal to any of its competitors at 5.5 feet. No. 2 and No. 7 burners were tried with the utmost quantity which could be consumed in them without smoking or burning advantageously.

Though these experiments indicate the relative adaptation of the several burners for the combustion of Newcastle coal-gas, they must not be taken as settling the question of the practical value of each. Some of them cast shadows, which detract considerably from the light they yield when placed above the level of the eye; this is particularly the case with No. 5, which otherwise gives the best results. Others, like No. 7, require a perfect uniformity of pressure, and an absence of all currents of air. Taking all things into consideration, No. 8 is, perhaps, the one to which these objections least apply, and it gives the next largest amount of light for the gas consumed, though the slight advance upon the old argand, as constructed twenty-five years since, cannot fail to be remarked.

Glass chimneys are not so requisite for gas as for lamp flames, and their effect is quite different from that exerted upon the wick flame of a lamp. The jet of gas, as it leaves the burner, is in far more correct relation to the air, than is the case with the gas produced at the burning margin of the wick.

Argand wick flames require a strong draught, and never burn without smoke, unless a chimney is used; with gas flames, the glasses are used rather to steady the flame than to insure its perfect combustion: they are always made shorter than the glasses of oil-lamps. If too high chimneys are used, the draught of air soon cools the base of the flame, and the air becoming mixed with the gas, a diminution of the light results,

which is caused by the combustion of too much carbon simultaneously with the hydrogen; hence but little is momentarily separated in the flame. A striking proof of this is afforded by the well-known experiment, in which a closed cylinder of wire-gauze, through which flame cannot be communicated to a combustible mixture, is adapted to a gas-burner. The jet of gas which, without the case of wire-gauze, yields a perfect flame, becomes intimately mixed with air in the interior of the case, and on its exit burns with a pale blue light, because the separation of carbon in the flame no longer occurs, both carbon and hydrogen being burnt simultaneously. This experiment gives an important hint on the general management of the draught in illumination. The same result may be observed when the gas is allowed to escape with too great velocity; and, if the proper limit is exceeded, the flame may be extinguished by being too much cooled: with a certain velocity, the current will not ignite for a distance of several lines from the aperture, and then burns with a faint blue flame, the gas having become mixed with air.

It is by taking advantage of this effect of a strong current of air, that the highly carbonaceous vapors of oil of turpentine, coal-tar naphtha, and similar substances, may be burned without smoke, as in BUSSON and ROUEN's apparatus, or in HOLLIDAY's lamps. The oils being allowed to escape in the form of a jet of vapor, under a pressure varying, according to circumstances, from four to twenty-four lines of mercury, the excess of carbon is brought to a proper proportion by the admixture of air, without interference with the order of combustion. In this manner brilliant flames, free from soot, are produced.

Among the arrangements which increase the light by raising the temperature of the air, the burner invented by M. PARISOT of Paris is distinguished by its simplicity and great facility of construction. It admits the air by narrow passages between two thick concentric cylinders or cones, about four inches in height. The gas escapes by a circular slit, easy to clean. This burner gives a full light and a very steady flame.

Application of Gas as a source of Heat.—Gas has long been employed as a source of heat in chemical and pharmaceutical laboratories, but it is only during the last few years that it has been more extensively used for cooking, warming apartments, *et cetera*.

Comparison of the various methods of Illumination with each other.—In the foregoing remarks, the relative illuminating values of the various methods of producing artificial light have generally been shown, without reference to the cost of the light. This still remains to be considered, in order to estimate their relative economy. PECLET, in the following sketch, has in each case taken the cost into account; but this will vary with the rise and fall of markets, and with the locality. The price of a pint of oil—0.9 lb.—is here fixed at about fivepence; of one pound of tallow candles at sevenpence, wax candles at two shillings and twopence, stearin candles at one shilling and fourpence; a pint of illuminating spirit—0.8 lb.—at eightpence; of one hundred cubic feet of coal-gas at sevenpence; and lastly, of one hundred cubic feet of oil-gas at two shillings and threepence.

Means of Illumination.	Intensity of the light.	Consumption of illuminating material per hour.	Illuminating power, Carcel's lamp = 100.	Price of 100 grammes of illuminating matter.	Cost of the light per hour in pence.	Cost of a light of the same intensity per hour in pence.
Tallow candles, six to lb.,	10.66	8.5	54.04	1.5	0.125	1.169
Wax " six "	14.60	9.6	61.57	5.	0.461	3.155
Stearin " five "	14.40	9.3	66.58	3.2	0.298	2.066
Kitchen lamp,	6.65	8.0	33.60	1.4	0.083	1.246
Lamp with flat wick,	12.50	11.0	47.50		0.114	0.912
Astral lamp,	31.00	26.7	48.70		0.280	0.893
Sinumbra lamp,	56.00	37.1	63.0		0.385	0.687
Lamp with inverted reservoir,	90.00	43.0	87.8	1.3 Per 100	0.446	0.495
Hydrostatic lamp,	45.00	17.26	109.2		0.179	0.398
Carcel's lamp,	100.00	42.0	100.0		0.435	0.435
Vapor lamp,	130.70	151.0	36.2		2.013	1.207
Coal-gas, ..	127.00	C. F.	8.70	C. F.	0.580	0.456
Oil-gas, ..	127.00	2.43		19.2	0.630	0.367

The light of wax caudles is the most expensive, then that of stearin candles and the vapor lamp, which are also costly. There are, however, few instances in which public opinion and scientific estimation of the value of an article are so much at variance as with reference to the means of illumination in general; occasional deceptions, such as occur in the lamp of BENKLER, not being taken into consideration. A glance at the last column in the above table shows that the modes of illumination which, on account of their supposed cheapness, are partly used by the wealthy and exclusively by the poor, are those which—excluding

articles of luxury, such as wax, *et cetera*—cost most in producing a certain degree of brilliancy. A given amount of light yielded by tallow candles costs from three-fifths to twice as much as when it is obtained from the lamp of CARCEL; with the kitchen lamp it costs nearly three times, and by the lamp with the flat wick more than twice as much.

The more ordinary light-giving materials have recently been examined, and compared with the light obtained from what is called common or thirteen-candle coal-gas. Tried by the photometer:—

One thousand cubic feet of gas were found equal to the light of 312,000 grains, or 44½ pounds of sperm candles.	
" " " " " 341,750 " 48½ pounds of carefully-snuffed wax candles.	
" " " " " 358,000 " 51½ pounds of stearic acid candles.	
" " " " " 370,540 " 52½ pounds of best mould candles.	
" " " " " 381,000 " 54½ pounds of best dip candles.	
" " " " " 417,220 " { 6½ gallons of purified colza oil specific gravity 915.	
" " " " " 366,310 " 5½ gallons of sperm oil, specific gravity 888.	

As the price of gas varies in different parts of the United Kingdom from four shillings and sixpence to ten shillings per thousand cubic feet, to obtain the relative cost it is necessary to multiply the prices of the other materials per pound with the numbers in the above table.

Thus, with gas at four shillings and sixpence per thousand cubic feet, and dip candles at sevenpence per pound, the cost of an equal amount of light from the two sources will be as four shillings and sixpence to one pound ten shillings and tenpence.

The great obstacles to the more general introduction of gas-light into private houses, are the difficulty of placing the light in such a position as to be available for all purposes, and that of reducing the consumption to the requirements of the consumer. A candle or a lamp can be placed wherever it is wanted, while a gas-light, even when flexible india-rubber tubes are used, is always more or less a fixture. The burners in common use are also calculated for giving more light than is required for one or two persons; and hence, though the light from gas is so very much cheaper, yet a larger quantity of light than is absolutely necessary being generally employed wherever gas is introduced, the

actual saving by its introduction is not so great as the difference of price in the light would make it appear.

The foregoing tables also show that the most economical light is obtained from the best constructed lamps, which, in addition to being costly themselves, also consume large quantities of oil, and are therefore not economical when used by a single person. There still appears much room for improvement in the adaptation of good lamps to the requirements of small consumers. A lamp which would give the light of one or two spermaceti candles, and yet be relatively as economical in the consumption of oil as CARCEL's or the French moderator lamp, would probably command an extensive sale.—*Richardson and Ronalds.*

Detection of Sulphide of Hydrogen, Bisulphide of Carbon, and Atmospheric Air in Coal-Gas.—A quick approximative method of estimating the above in coal-gas, which has long been considered a great desideratum by chemists, has been given by THORNTON J. HERAPATH. The reagents and apparatus required are:—

1. A weak aqueous solution of caustic potassa.
2. A strong alcoholic solution of caustic potassa.

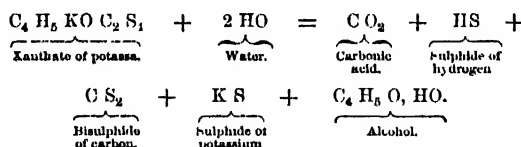
3. A solution of the nitrate or acetate of lead.

4. A standard solution of lead, containing one, two, or three one-hundredths of a grain of metallic lead, as nitrate or acetate, to one hundred or one thousand water-grain measures of solution.

5. A standard meter, such as is generally used for testing the illuminating quality of coal-gas.

6. Two Liebig's triangles, and

7. Three graduated tubes or colorimeters of uniform bore. The aqueous solution of potassa is used to absorb the sulphide of hydrogen, whilst the alcoholic is afterwards employed to dissolve the bisulphide of carbon vapor, which it converts into xanthate of potassa, a salt decomposable by heat into sulphide of potassium, sulphide of hydrogen, *et cetera*, as exhibited by the equation:—



In testing a gas by this method, one proceeds as follows:—The two triangles having been properly filled, the one with the aqueous, and the other with the alcoholic solution of caustic potassa, they are connected together by a piece of sheet caoutchouc in the usual way, and attached to the exit pipe of the standard meter, care being taken to place the one containing the aqueous solution next to the exit pipe. A known quantity, say ten, twenty, or thirty cubic feet of the gas to be examined, is then tardily transmitted through the triangles; the apparatus is slowly disconnected, and the contents of the triangles are separately poured into two different colorimeters. The solutions are next diluted with a little distilled water, mixed with a few drops of a solution of lead, and the alcoholic solution is heated to the boiling point, or until no further darkening in color ensues. The caustic alkali of both solutions is then supersaturated either with acetic or with very dilute nitric acid, and water is added to dilute to the required degree. As the sulphide of lead produced by the decomposition of the xanthate of potassa that was contained in the alcoholic solution is generally, if not always, much less in quantity than that produced by the sulphide of hydrogen absorbed by the aqueous solution of the alkali, it is advisable to dilute the former with less water. The depth of tint communicated to the fluid by the sulphide of lead in the alcoholic solution, is then compared with that produced, by adding the standard solution of lead, drop by drop, from a graduated tube, into a third colorimeter, which is filled nearly up to the same mark with distilled water, mixed with a few drops of pure citric acid, and of a solution of sulphide of hydrogen. So soon as the tints correspond, the measure of the solution in the two colorimeters is accurately adjusted by adding a little more water either to the one or the other; a little more of the standard solution of lead is then poured in, if requisite, to the trial colorimeter, and the number of measures of the standard solution that has been taken is carefully noted. The operation is then repeated with

the contents of the other colorimeter, containing sulphide of lead from the aqueous solution of potassa; and the number of measures of the standard solution of lead taken, is again read off. By a simple calculation are estimated the relative proportions of bisulphide of carbon and sulphide of hydrogen, by weight, contained in the gas examined.

For example, let *a* represent the quantity by weight of bisulphide of carbon which is equivalent to the lead contained in one thousand grain measures of the standard plumbous liquid; *b* the quantity of sulphide of hydrogen equivalent to the lead contained in the same bulk of the standard solution taken, as before explained, to produce a tint equal in intensity to that of the sulphide of lead in the alcoholic solution; and *d* the number of measures of the same solution by the aqueous solution:—then the proportion by weight of sulphide of carbon and sulphide of hydrogen contained in the number of cubic feet of gas operated upon, is obtained in the following equations:—

$$\text{Bisulphide of carbon,} \dots\dots\dots = \frac{a + a}{1000} + 2 \text{—nearly.}$$

$$\text{Sulphide of hydrogen,} \dots\dots\dots = \frac{d + a}{1000}$$

And as one hundred cubic inches of bisulphide of carbon vapor, and sulphide of hydrogen, weigh respectively at 600°, and 30 inches of Bar. 81·8167 and 36·331 grains, the result of the above calculation affords the means of ascertaining the proportion of these two substances by volume.

The presence of atmospheric air in coal-gas can be readily detected, by collecting a portion of the gas over mercury, and then passing up, first a few drops of caustic potassa, and afterwards a drop or two of a solution of pyrogallie acid. If the liquid assume a blood-red hue, oxygen, indicating the presence of atmospheric air, is mixed with the gas.

It would be quite out of place in a work like this to enlarge upon the different varieties of gas-burners, as that subject relates more particularly to mechanics. Still the Editor will cursorily glance at them, and for this purpose he cannot do better than append the following remarks from the able work of Drs. RICHARDSON and RONALDS:—

The Burners.—From the leaden pipes—in the circuit of which the meter is placed, if used at all—the gas passes to the *burners*, each of which is furnished with a separate brass tap. Good tight stopcocks are much more difficult to make for so light a substance as gas, than for liquids. The burners are very similar to those used for lamps, but as neither wick nor oil level requires special consideration, the management of the gas-burners is comparatively simple. The amount of gas consumed in a given time, however, must bear a proper relation to the supply of air, that the flame may not smoke or burn with a blue flame. This is regulated partly by the tap attached to the burner, and an excess of gas is avoided by making the aperture of the burners very small, which increases the velocity of the current. The same quantity of gas issuing from a wide orifice would produce a thick, short, and dull flame, because the surface in contact with the air would be increased. No gas flame should be allowed to issue from a wide open-

ing, for the same reason that thick massive lamp-wicks are not desirable.

When the burner has a single aperture of the diameter of a bristle, a *simple jet* is produced in the form of a long, thin, conical flame. The *bat's-wing*, or flattened flame, which the gas forms when it issues from a narrow slit, instead of a round aperture, is much more appropriate. A similar and equally good flame is produced by a burner with two apertures close to each other, the channels of which are inclined inwards, so that both the currents of gas cross each other at the base. They then form a flat flame spreading out in the form of an inverted triangle, and the burner is called a *fish* or *swallow-tail*.

Simple flames of this kind are generally burnt without any chimney. When a greater quantity of light is required, a greater intensity of flame, the argand burner, Fig. 122, is generally chosen. The gas from the pipe enters the annular space, *a*, which is closed above by the flat plate, *b*, Fig. 123. In this plate are a number of fine apertures, arranged in a circle, and so near to each other that the separate flames unite to form a hollow cone. The gallery, *c*, supports the chimney, *d*; and to produce an internal current of air, *e*, is open at the sides. The distance between the apertures in these burners varies with the quality of the gas, as does the size of the aperture itself. An aperture $\frac{3}{8}$ of an inch is often used for coal-gas, and one of $\frac{7}{16}$ of an inch for oil-gas; for the former they should be $\frac{1}{8}$ th of an inch, for the latter $\frac{1}{4}$ th of an inch apart. These dimensions are, therefore, larger for coal-gas than for oil-gas, the latter possessing double the illuminating power of the former. The holes should be as uniformly and accurately bored as possible; if this is not done, there will be parts of the flame which will smoke. Sometimes the heat of the flame is applied to warm the current of gas before it issues from the burner, by which means the flame is less cooled, and whiter light is produced. For this purpose, the gas-pipe is formed into several revolutions at a certain height above the flame.

An important improvement upon ARGAND's burner for illuminating public places, bridges, *et cetera*, where one large lamp, and a very intense light, is preferred to a number of small ones, is the *bude burner*, proposed by GURNEY, upon the principle of FRESNEL's lamp. Two, three, or more hollow ring tubes, each furnished at the top with a circle of holes, form the principal part of the burner, and are connected at bottom with parts of the gas-pipe bent horizontally, from which they receive the gas. Each inner ring is placed somewhat higher than the one before it, so that a number of concentric flames are produced, the light of which is thrown by reflectors in the proper direction. The *bude burner* must not be confounded with the *bude light* of the same inventor, which is produced by conveying oxygen into the inner space of an argand oil-lamp. A similar effect

to that of the *bude burner*, is produced by a number of single flat flames arranged in a ring. The Victoria Bridge at Manchester, for instance, is lighted by such a burner, consisting of two concentric rings, each containing twelve, therefore altogether containing twenty-four flat flames; the inner ring, four inches in diameter, stands one inch higher than the outer, which is six and a half inches in diameter, the whole thus being rounded off in the shape of a rose. A great variety of gas-burners have been successively brought into public notice, all of which lay claim to the production of an increase of light, with a smaller consumption of gas. It is impossible, however, from a mere inspection of the flame produced by these burners, without accurately measuring the amount of gas consumed by each, to arrive at any conclusion as to which form is the most economical or generally desirable. Until, as RICHARDSON and RONALDS justly remark, impartial comparative experiments have been instituted with them all, decided preference cannot be awarded to any one in particular.

Fig. 124 is a representation of WINFIELD's lucent burner, in which the Liverpool button is applied to an argand gas-burner, and the peculiar form of chimney causes an external current of air to impinge at a certain angle upon the flame, producing the same effect as the metallic cone in the solar lamp; a basket of wire-gauze is fitted into the crutch of the burner, which moderates the supply of air from below, and prevents the flickering caused by sudden draughts. By fixing the chimney to a circular collar, which screws up or down upon the triangular support, Mr. LOWE is enabled, in his improvement upon this form of burner, to alter the direction of the external current caused by the contraction of the chimney; and by converting the button into a screw, its height can also be altered, and the internal current regulated.

Fig. 125 shows a form of burner, patented by Mr. LESLIE, in which the gas is caused to flow through a



Fig. 123.



Fig. 124.

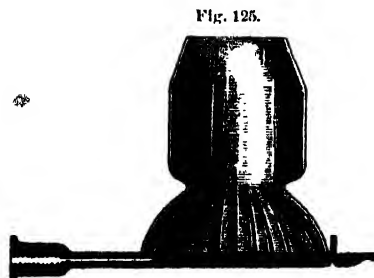


Fig. 125.

number of small copper tubes, instead of from the apertures of an argand burner. The object of this is to effect a more complete combustion of the gas, by surrounding each single jet with abundance of air as it issues from the orifice. A low form of chimney or combustion-chamber is adapted to this burner, which

diminishes the velocity of the draught. If the gas be impure, the orifices of the copper tubes become stopped up either with sulphide of copper or ammoniacal compounds, and require to be cleansed with a stiff brush. The only effectual remedy for this objection to the burner, is the use of purer gas; and this must be obtained, when not supplied in a pure state from the gas-works, by the use of a separate purifier in each house. —*Richardson and Ronalds.*

Ventilation of Gas-burners.—Serious objections stood in the way of using gas-light in private dwellings at first, in consequence of the impurities contained in the gas, the great heat produced, and the large quantity of carbonic acid evolved; and to avoid inconvenience, some system of ventilation had to be adopted; but now, owing to the general purity of the gas, and the loftiness of rooms, this is not necessary.

HOFMANN'S BURNER.—It will not be out of place here to remark, that the very extensive and daily increasing application of gas as a source of heat, suggested to HOFMANN a small contrivance which is intended to facilitate the operations of the analyst.

The ordinary argand gas-burner, which is almost universally employed for heating small vessels, such as flasks, retorts, and test-tubes, is not adapted to the purposes of the blowpipe. In operations with the latter instrument, a simple jet of gas is required, issuing from a cylindrical orifice of rather considerable dimensions, the necessary amount of gas being adjusted by the stopcock. This simplest of all gas flames serves equally well for oxidation and reduction, and exhibits the phenomena of color in the most conspicuous manner.

The ordinary method of analysis being a combination of testing in the moist way and by the blowpipe, it is necessary either to use the two gas lamps—the one

with the argand burner, the other with the single jet—or to have a gas-stand so arranged as to admit of screwing on either the one or the other. But as it is inconvenient to multiply the number of gas lamps, especially in a laboratory in which several analytical students are working, and as unscrewing hot gas-jets is a most unpleasant operation, the above chemist endeavored to unite the two jets in one stand, dispensing, at the same time, with the necessity of taking the apparatus to pieces.

The object in view is accomplished simply by

substituting for the ordinary stopcock a three-way tap. The whole arrangement becomes at once intelligible by a glance at the woodcut, which represents the burner half size.

A is the loaded foot, into which the elbow union-

piece, B, is screwed. One end of this union is connected with a flexible pipe, not shown in the drawing; to the other screws the three-way stopcock, C. The plug, D, has only one orifice, and, when turned in a vertical direction, supplies the argand burner through the perforation, E. Into the side of the stopcock is soldered a small pipe, F, having a bore of about one-eighth of an inch. This is prolonged to the distance of one-tenth of an inch above the top of the argand burner, where it is brazed to a small support for the blowpipe, not represented in the drawing.

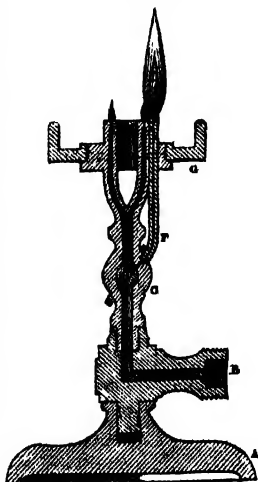
When the plug, D, is turned in a horizontal direction, the gas is shut off from both jets, but when turned in an inclined position, may be made to supply both jets at once, or either alternately. By this contrivance, either of the jets will be lighted before the other is extinguished.

In order that the jet may be likewise used for heating larger apparatus, there is a support, G, on which may be fixed a copper chimney, either plain or provided with the wire-gauze for producing the air flame.

ANALYSIS OF COAL-GAS.—The accurate analysis of gaseous mixtures—says Dr. FRANKLAND, in an able paper published in *Clegg's Treatise on Coal-Gas*, from which the following method is extracted—is one of the most delicate operations of modern chemistry. This arises not only from the difficulty of preserving gases, during the requisite manipulation, free from admixture with atmospheric air; but also from the circumstance, that their volume, the measurement of which is, in most cases, the only means of estimating their quantity, is liable to constant and considerable change, by fluctuations of temperature and of the pressure of the atmosphere, as well as by the dryness or humidity of the gas itself. This branch of chemical analysis owes much of its present accuracy and perfection to the admirable researches of Professor BUNSEN of Heidelberg.

All analytical operations upon gases must be conducted over mercury, which metal should be placed in a small wooden pneumatic trough, with plate-glass sides. The eudiometers, or measuring tubes, should be accurately calibrated and graduated into cubic inches and their tenths, the latter being subdivided by the eye into hundredths, when the volume of a gas is read off: such a division is readily attained by a little practice. At each determination of volume, it is necessary that the gas should either be perfectly dry, or quite saturated with moisture. The first condition is attained by placing in the gas for half an hour, a small ball of fixed chloride of calcium, attached to a platinum wire; the second, by introducing a minute drop of water into the head of the eudiometer before filling it with quicksilver. The determinations of volume must either be made when the quicksilver is at the same level inside and outside the eudiometer; or, as is more frequently done, the difference of level must be accurately measured in the subsequent reduction to a standard pressure. The height of the barometer, and the temperature of the surrounding atmosphere, must also be observed each time the volume of gas is measured, and proper corrections made for pressure, temperature, and also the tension of aqueous vapor, if the gas be moist.

Fig. 120.



The process of analysis described below has reference to purified coal-gas; the method of detecting the principal impurities being given in a former page.

1. *Estimation of Carbonic Acid.*—A few cubic inches of the gas are passed into a short eudiometer, moistened as above described; the volume is accurately noted with the proper corrections, and a bullet of caustic potassa is then passed up through the mercury into the gas, and allowed to remain for at least an hour; the volume of the gas being ascertained and deducted from the first volume, gives the amount of carbonic acid which has been absorbed by the potassa. Bullets of caustic potassa, or of any other fusible substance, should be of the size of a large pea, and may be prepared by melting the materials in a crucible, and then pouring them into a small bullet-mould, in which the curved end of a fine platinum wire has been placed. The ball attached to the wire is easily removed when cold.

2. *Estimation of Oxygen.*—LIEBIG has devised very accurate means for the estimation of this element, depending upon its rapid absorption by an alkaline solution of pyrogallic acid. To apply this menstruum, a small test-tube is filled with mercury and inverted in the trough: first, a few drops of pyrogallic acid, and then a similar quantity of *aqua potassæ*, are introduced into this tube by means of a pipette; a coke bullet—made by filling a bullet-mould containing a platinum wire with a mixture of two parts of coke and one of coal, both finely powdered, and then exposing the mould and its contents to a heat gradually increased to redness for fifteen minutes—attached to a platinum wire, is introduced into this liquid, and allowed to become saturated; it is then withdrawn, and conveyed carefully below the surface of the mercury into the eudiometer containing the residual gas of the first determination. Every trace of oxygen will be absorbed in a few minutes, and the volume being again measured, the diminution from the last reading will represent the amount of oxygen originally present in the gas. It is essential that the coke-bullet, after saturation with the alkaline solution of pyrogallic acid, should not come into contact with the air before its introduction into the gas.

3. *Estimation of the Luminiferous Constituents.*—Various methods have been employed for the estimation of the so-called olefiant gas—luminiferous constituents—in coal-gas. That which has been most generally employed depends upon the property which is possessed by olefiant gas and most hydrocarbons, of combining with chlorine, which causes their condensation to the state of an oily liquid. Hydrogen and light carbide of hydrogen are both acted upon in a similar manner, when a ray, even of diffused light, is allowed to have access to the mixture; but the condensation of olefiant gas and hydrocarbons takes place in perfect darkness, and advantage is, therefore, taken of this reaction to observe the amount of condensation which takes place when the mixture is excluded from light; the volume which disappears during this action of the chlorine being regarded as indicative of the quantity of olefiant gas present in the mixture. There are many sources of error inseparably connected with this

method of operating, which render the results unworthy of the slightest confidence. The same remark will equally apply to the employment of bromine in the place of chlorine. In addition to the circumstance that these determinations must be made over water, which allows a constant diffusion of atmospheric air into the gas, and *vice versa*, there is also formed in each case a volatile liquid, the tension of the vapor of which augments the volume of the residual gas, and this increase admits of neither calculation nor determination.

The only material by which the estimation of the luminiferous constituents can be accurately effected, is anhydrous sulphuric acid, which immediately condenses the hydrocarbons, but has no action upon the other ingredients, even when exposed to sunlight. The estimation is conducted as follows:—A coke bullet, prepared as described above, and attached to a platinum wire, being rendered thoroughly dry by gently heating it for a few minutes, is quickly immersed in a saturated solution of anhydrous sulphuric acid, and allowed to remain for one minute; it is then withdrawn, leaving as little acid adhering to it as possible, quickly plunged beneath the mercury in the trough, and introduced into the same portion of dry gas from which the carbonic acid and oxygen have been withdrawn. Here it is allowed to rest for about two hours, in order to insure the complete absorption of every trace of carbide of hydrogen. The residual volume of the gas cannot, however, yet be determined, owing to the presence of some sulphurous acid derived from the decomposition of a portion of the sulphuric acid. This is absorbed in a few minutes by the introduction of a moist ball of binoxide of manganese, which may be readily made by converting the finely-powdered binoxide into a stiff paste with water, rolling it into a globular shape, and then inserting a bent platinum wire in such a manner as to prevent its being readily withdrawn; the ball being gradually dried, it will become hard, and possess considerable cohesion, even after being moistened with water, previous to its introduction into the gas. After half an hour the manganese bullet may be withdrawn, and replaced by one of caustic potassa, to remove the aqueous vapor introduced with the previous one; in half an hour this bullet can be removed, and the volume of the gas at once noted. The difference between this and the previous reading gives the volume of the luminiferous constituents of the gas. This method is very accurate; according to its author, Dr. FRANKLAND, the per centage of luminiferous constituents seldom varies, in two analyses of the same gas, more than .01 or .02.

4. *Estimation of the Non-luminous Constituents.*—These are, light carbide of hydrogen, hydrogen, carbonic oxide, and nitrogen. Their per centages are ascertained in a graduated eudiometer, about two feet in length, and three-fourths of an inch internal diameter, the thickness of the glass being not more than one-tenth of an inch. This eudiometer is furnished, at its closed end, with two platinum wires fused into the glass, for the transmission of the electric spark. A drop of water, about the size of a pin's head, is introduced into the upper part of the eudiometer before it is filled with quicksilver, and inverted in the mercurial trough; this

small quantity of water serves to saturate with aqueous vapor the gases subsequently introduced. About a cubic inch of the residual gas from the last determination is passed into the eudiometer, and its volume accurately read off; about four cubic inches of pure oxygen are now introduced, and the volume—moist—again noted. The oxygen is best prepared at the moment when it is wanted, by heating, over a spirit or gas flame, a little chlorate of potassa in a very small glass retort, allowing sufficient time for every trace of atmospheric air to be expelled from the retort before passing the gas into the eudiometer. The open end of the latter must now be pressed firmly upon a thick piece of caoutchouc placed at the bottom of the trough, and an electric spark passed through the mixture. If the above proportions have been observed, the explosion will be but slight, which is essential if nitrogen be in the mixture, as this element will otherwise be partially converted into nitric acid, the results being thus vitiated. By using a large excess of oxygen, all danger of the bursting of the eudiometer by the force of the explosion is also avoided. The volume after explosion being again determined, a bullet of caustic potassa is introduced into the gas, and allowed to remain so long as any diminution of volume takes place. This bullet absorbs the carbonic acid produced by the combustion of the light carbide of hydrogen and carbonic oxide, and also renders the residual gas perfectly dry; the volume noted after this absorption, when deducted from the previous one, gives the volume of carbonic acid generated by the combustion of the gas.

The residual gas now contains only nitrogen, and the excess of oxygen employed.

The former is determined by first ascertaining the amount of oxygen present, and then deducting that number from the volume of both gases; for this purpose, a quantity of dry hydrogen, at least three times as great as the residual gas, is introduced, and the bulk of the mixture determined; the explosion is then made as before, and the volume—moist—again recorded. One-third of the contraction caused by this combination represents the amount of oxygen, and the remainder, when this is deducted from the volume of residual gas, after absorption of carbonic acid, shows the quantity of nitrogen.

The behavior of the other three non-luminous gases on explosion with oxygen, enables the operator readily to find their respective amounts by three simple equations, founded upon the quantity of oxygen consumed, and the amount of carbonic acid generated by the three gases in question. Hydrogen consumes half its volume of oxygen, and generates *no* carbonic acid; light carbide of hydrogen unites with twice its volume of oxygen, and generates *its own volume* of carbonic acid; whilst carbonic oxide combines with half its volume of oxygen, causing the formation of *its own volume* of carbonic acid.

If, therefore, the volume of the mixed gases be represented by A; the amount of oxygen taken up, by B; and the quantity of the mixed gases generated, by C; and further, the volumes of hydrogen, light carbide of hydrogen, and carbonic oxide respectively, by x , y , and z , the following equations arise:—

$$\begin{array}{rcl} x + y + z & = & A \\ \frac{1}{2}x + 2y + \frac{1}{2}z & = & B \\ y + z & = & C \end{array}$$

From which the annexed values for x , y , and z are derived:—

$$\begin{aligned} x &= A - C \\ y &= \frac{2B - A}{3} \\ z &= C - \left(\frac{2B - A}{3} \right) \end{aligned}$$

5. Estimation of the Value of the Luminous Constituents.—The methods above given will show the respective quantities of all the constituents in any specimen of coal-gas; but analytical results afford no clue to its illuminating power; they give, it is true, the amount of illuminating hydrocarbons contained in a given volume of the gas, but it is evident, from what has already been said respecting the luminiferous powers of these hydrocarbons, that the greater the amount of carbon contained in a given volume, the greater will be the quantity of light produced on their combustion; and, therefore, as the number of volumes of carbon vapor contained in one volume of the mixed constituents, condensable by anhydrous sulphuric acid, has been found to vary from 2.54 to 4.36 volumes, it is clear that this amount of carbon vapor must be accurately determined for each specimen of gas, if it be desirable to ascertain the value of that gas as an illuminating agent. Fortunately, this is easily effected, for if the amount of carbonic acid generated by one hundred volumes of the gas in its original condition be ascertained, knowing from the preceding analytical processes the per centage of illuminating hydrocarbons, and also the amount of carbonic acid generated by the non-luminous gases, the operator has all the data for calculating the illuminating value of the gas. For this purpose a known volume—about a cubic inch—of the original gas is introduced into the explosion eudiometer, mixed with about five times its bulk of oxygen, the electric spark passed, and the amount of carbonic acid generated by the explosion ascertained, as before directed. If the per centage of hydrocarbons absorbed by anhydrous sulphuric acid be denoted by A; the volume of carbonic acid generated by one hundred volumes of the original gas, by B; the carbonic acid formed by the combustion of the non-luminous constituents remaining after the absorption of hydrocarbons from the above quantity of original gas, by C; and the volume of carbonic acid generated by the combustion of the luminiferous compounds—hydrocarbons—by x , one has the following equation:—

$$x = C - B;$$

and, therefore, the amount of carbonic acid generated by one volume of the hydrocarbons is represented by

$$\frac{C - B}{A}.$$

But, as one volume of carbon vapor gives rise to a similar quantity of carbonic acid, this formula also expresses the amount of the former in one volume of the illuminating constituents. For the purpose of comparison, however, it is more convenient to represent

the value of these hydrocarbons in their equivalent volume of olefiant gas, one volume of which contains two volumes of carbon vapor; for this purpose the last expression need only be changed to

$$\frac{C - B}{2 A}$$

Thus, if a sample of gas contain ten per cent. of hydrocarbons, of which one volume contains three of carbon vapor, the quantity of olefiant gas to which this ten per cent. is equivalent will be fifteen.

The application of this method furnishes an exact chemical standard of comparison for the illuminating value of all descriptions of gas; and by a comparison of the arbitrary numbers thus obtained, with the practical results yielded by the same gases when tested by the photometer, much valuable and useful information is gained.

Estimation of the Specific Gravity of Gas.—Although the mere determination of the specific gravity of gases is of very little use as a test of their commercial value—unless the gas is to be used for aeronautic purposes—yet, as it is still much employed by gas engineers, and as such an estimation is occasionally useful for controlling the results of chemical analysis, a method by which such a determination may be made is here subjoined.

The specific gravity of gases should be taken in a room where there is no fire, and where the temperature is liable to little variation during the time occupied in the operations. The following apparatus is necessary: First, a thin glass globe, capable of holding at least two hundred cubic inches, and furnished with a brass cap and stopcock, so accurately fitted as to prevent all ingress of air when the globe is exhausted; secondly, a small exhausting syringe or air-pump, to which the globe can be screwed air-tight; thirdly, a balance capable of weighing to one-fiftieth of a grain, when loaded with a quarter of a pound in each pan; fourthly, a glass tube, eighteen inches long, and half an inch in diameter, filled with fragments of fused chloride of calcium, and closed at each end with a perforated cork, through which passes a glass tube, of such dimensions as to admit of adaptation by means of caoutchouc tubing at one end, to the exit pipe of a small gas-holder, and at the other, to the stopcock of the glass globe.

The process consists in ascertaining the weight of equal volumes of atmospheric air, and of the gas under examination, at the same temperature and pressure. This is accomplished by first exhausting the globe by means of the syringe or air-pump, and then accurately ascertaining its weight, care being taken to allow time for the globe to assume the same temperature as that of the air surrounding the balance. The globe should then be connected with one extremity of the chloride of calcium tube, by means of a piece of vulcanized caoutchouc tube, and the stopcock being then very slightly opened, the air passing through the chloride of calcium, and thus being thoroughly deprived of moisture, should be allowed slowly to fill the globe. The latter being detached from the desiccating tube, is replaced in the balance, where it should remain undisturbed for at least

five minutes, when the stopcock is opened for a moment to equalize the pressure within and without, and the weight then accurately determined. The difference between the two determinations gives the weight of the air enclosed in the globe. The exsiccating tube should now be attached to the exit pipe of the gas-holder, and a stream of gas allowed to rush through it, until every trace of air has been expelled from the interstices of the chloride of calcium; the globe, again exhausted, is then to be attached to the other extremity of this tube, and the stopcock being slightly opened, as before, the gas, perfectly dried in traversing the fragments of chloride of calcium, is permitted slowly to fill the globe, which should, whilst still attached to the drying tube, be allowed to stand undisturbed for a few minutes near the balance, before the stopcock is finally closed and detached from the drying tube. The weight of the globe thus filled with gas is ascertained, and that of the exhausted globe being subtracted from it, the difference indicates the weight of the gas. The weight of equal volumes of gas and atmospheric air at the same temperature and pressure having now been ascertained, it only remains to divide the former by the latter to know the specific gravity of the gas. Thus, suppose the weight of the exhausted globe to be 2000 grains; that of the globe filled with dry air 2060, and with exsiccated gas 2040 grains; the weight of the volume of air equal to the contents of the globe would be sixty, and that of the same volume of gas forty grains; hence, $40 \div 60 = .6666$, the specific gravity of gas, air being taken as unity.

Unless a number of specific gravities are determined at the same time, it is indispensably necessary to ascertain the weight of the air contained in the globe previous to each determination. Care should be taken that the temperature of the room in which the balance is placed does not vary more than about one degree between the several weighings of the globe, as otherwise a considerable error will be introduced into the experiments. The globe should also be protected, as much as possible, from the heat radiating from the body of the operator during the several weighings.—*Clegg.*

Much time and space might be occupied in discussing the merits of the several apparatus to be employed in the analysis of gases, but this seems to the Editor to be quite unnecessary. The best plan will be to place before the reader the improved apparatus of FRANKLAND and WARD, which resembles that of REGNAULT and REISSET in mechanical arrangement, although it differs entirely in the mode adopted for the measurement of the gaseous volumes.

The instrument, which is represented by the accompanying figure, consists of the tripod, A, furnished with the usual levelling screws, and carrying the vertical pillar, B B, to which is attached, on the one side, the movable gutta-percha mercury trough, C, with its rack and pinion, *a a*, and on the other the glass cylinder, D D, with its contents. This cylinder is thirty-six inches long, and four inches internal diameter; its lower extremity is firmly cemented into an iron collar, *e*, the under surface of which can be screwed perfectly watertight upon the bracket plate, *d*, by the interposition of

a vulcanized caoutchouc ring. The circular iron plate, *d*, is perforated with three apertures, into which the caps, *eee*, are screwed, and which communicate below the plate with the T-piece, *E E*. This latter is furnished with a double-way cock, *f*, and a single-way cock, *g*, by means of which the tubes cemented into the sockets, *eee*, can be made to communicate with each other, or with the exit-pipe, *h*, at pleasure.

F G H are three glass tubes, which are firmly cemented into the caps, *eee*. *F* and *H*, which are only slightly shorter than the glass cylinder, are each from 15^{mm} to 20^{mm} internal diameter, and are selected of as nearly the same bore as possible, to avoid a difference of capillary action. The tube, *G*, is somewhat wider, and

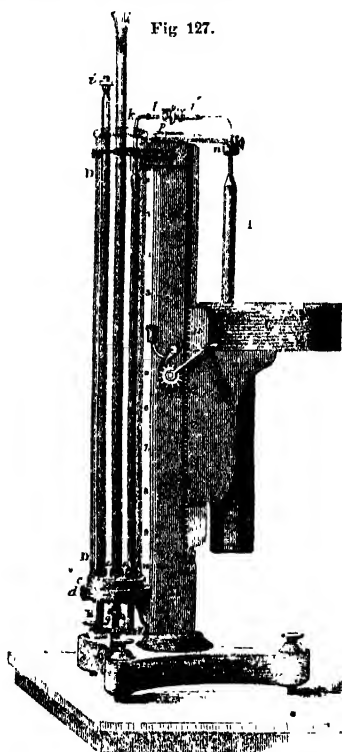


Fig. 127.

may be continued to any convenient height above the cylinder. *H* is accurately graduated with a millimetre scale, and is furnished at top with a small funnel, *i*, into the neck of which a glass stopper, about 2^{mm} in diameter, is carefully ground. The tube, *F*, terminates at its upper extremity in the capillary tube, *k*, which is carefully cemented into the small steel stopcock, *l*. *F* has also fused into it at *m* two platinum wires for the passage of the electric spark. After this tube has been firmly cemented into the cap, *e*, its internal volume is accurately divided into ten perfectly equal parts, which is effected without difficulty by first filling it with mercury from the supply-tube, *G*, up to its junction with the capillary attachment, and then allowing the mercury to run off through the nozzle, *h*, until the highest point of its convex surface stands at the division ten, previously made so as exactly to coincide with the zero of the millimetre scale on *H*; the weight of the mercury thus run off is carefully determined, and the tube is again filled

as before, and divided into ten equal parts, by allowing the mercury to run off in successive tenths of the entire weight, and marking the height of the convexity after each abstraction of metal. By using the proper precautions with regard to temperature, *et cetera*, an exceedingly accurate calibration can in this way be accomplished.

The absorption tube, *I*, is supported by the clamp, *n*, and connected with the capillary tube, *k*, by the stopcock and junction-piece, *l p*.

When the instrument is thus far complete, it is requisite to ascertain the height of each of the nine upper divisions on the tube above the lowest or tenth division. This is very accurately effected in a few minutes, by carefully levelling the instrument, filling the tube, *G*, with mercury, opening the cock, *l*, and the stoppered funnel, *i*, and placing the cock, *f*, in such a position as to cause the tubes, *F H*, to communicate with the supply-tube, *G*. On now slightly turning the cock, *g*, the mercury will slowly rise in each of the tubes, *F* and *H*; when its convex surface exactly coincides with the ninth division on *F*, the influx of metal is stopped, and its height in *H* accurately observed; as the tenth division on *F* corresponds with the zero of the scale upon *H*, it is obvious that the number thus read off is the height of the ninth division above that zero point. A similar observation for each of the other divisions upon *F* completes the instrument.

Before using the apparatus, the large cylinder, *D D*, is filled with water, and the internal walls of the tubes, *F* and *H*, are, once for all, moistened with distilled water, by the introduction of a few drops into each, through the stopcock, *l*, and the stoppered funnel, *i*. The three tubes being then placed in communication with each other, mercury is poured into *G*, until it rises into the cup, *i*, the stopper of which is then firmly closed. When the mercury begins to flow from *l*, that cock is also shut. The tubes *F* and *H* are now apparently filled with mercury, but a minute and imperceptible film of air still exists between the metal and glass; this is effectually got rid of by connecting *F* and *H* with the exit-tube, *h*, and permitting the mercury to flow out until a vacuum of several inches in length has been produced in both tubes. On allowing the instrument to remain thus for an hour, the whole of the film of air above-mentioned will diffuse itself into the vacuum, and will become visible as a minute bubble in each tube, on allowing the vacuum to be filled up from the supply-tube, *G*. These bubbles are, of course, easily expelled, on momentarily opening the cock, *l*, and stopper, *i*, whilst *G* is full of mercury. The absorption-tube, *I*, being then filled with quicksilver, and attached to *l* by the screw clamp, the instrument is ready for use.

In localities where a constant supply of water from street mains can be had, the temperature of the water in the cylinder, *D D*, can be maintained perfectly constant by allowing a continuous stream, direct from the main, to flow into the bottom of the cylinder, and make its exit near the top. By this arrangement it has been proved, in an extensive series of experiments, that the temperature of a cylinder supplied from the Manchester high-pressure mains varies so very little in twelve hours, that it scarcely requires correction in the most delicate experiments.

In illustration of the manner of using the apparatus, let one take as an example the analysis of atmospheric air. A few cubic inches of air freed from carbonic acid having been introduced into the tube, *r*, it is transferred into *F* for measurement by opening the cocks, *ll*, and placing the tube, *F*, in communication with the exit-pipe, *h*; the transference can be assisted, if needful, by elevating the trough, *c*. When the air, followed by a few drops of mercury, has passed completely into *F*, the cock *l* is shut, and *f* turned, so as to connect *F* and *II* with *h*. Mercury is allowed to flow out until a vacuum of two or three inches in length is formed in *II*, and the metal in *F* is just below one of the divisions; the cock, *f*, is then reversed, and mercury very gradually admitted from *G*, until the highest point in *r* exactly corresponds with one of the divisions upon that tube; suppose it to be the sixth division. This adjustment of mercury, and the subsequent readings, can be very accurately made by means of a small horizontal telescope, placed at a distance of about six feet from the cylinder, and sliding upon a vertical rod. The height of the mercury in *II* must now be accurately determined, and if, from the number thus read off, the height of the sixth division above the zero of the scale on *II* be deducted, the remainder will express the true volume of the gas; but, in order to compare this with subsequent readings, made at other divisions upon *F*, the number thus obtained, which evidently represents the pressure of the gas, is reduced to what it would have been had the gas been expanded to the tenth division of *F*. Bearing in mind that the pressure of a gas is inversely as its volume, this reduction is very simply effected by multiplying the number as above obtained by six-tenths, or 0.6; and, in all cases, any determination of pressure made at any division upon *F* may be reduced to the pressure of the same volume when expanded to the tenth division, by the use of a fractional multiplier, the denominator of which is ten, and the numerator, the number of the division at which the determination is made.

As the temperature is maintained constant during the entire experiment, no correction on that score has to be made; the atmospheric pressure being altogether excluded from exerting any influence upon the volumes or pressures, no barometrical observations are requisite, and, as the tension of aqueous vapor in *F* is exactly balanced by that in *II*, the instrument is, in this respect, self-correcting.

Hydrogen being then introduced in the same way as the original gas, and the volume determined anew, the electric spark is passed through the mixture by means of the platinum wires at *m*, and the determination of the contraction caused by the explosion terminates the process. The following are the results of an analysis of air made in this way:—

VOLUME OF AIR USED.

(Determination at fifth division on *F*.)

Observed height of mercury in <i>II</i> ,	673.0 mm
Height of fifth division above zero,	383.0 "
Corrected pressure of gas,	= 290.0 "
	.5 "
Corrected pressure of gas at tenth division,	= 145.00 "

VOLUME AFTER ADMISSION OF HYDROGEN.

(Determined at sixth division.)

Observed height of mercury in <i>II</i> ,	772.3 mm
Height of sixth division above zero,	304.0 "
Corrected pressure of gas,	= 468.3 "
	.6 "
Corrected pressure of gas at tenth division,	= 280.98 "

VOLUME AFTER EXPLOSION.

(Determined at fifth division.)

Observed height of mercury in <i>II</i> ,	763.3 mm
Height of fifth division above zero,	383.0 "
Corrected pressure of gas,	380.3 "
	.5 "
Corrected pressure of gas at tenth division,	= 190.15 "

RESULTS.

Volume of air used,	145.000
Volume of oxygen,	30.276

Hence:

Nitrogen,	79.120
Oxygen,	20.880
	100.000

Subjoined are the results of a series of analyses performed upon the same specimen of atmospheric air, previously freed from carbonic acid by caustic potassa, which show the delicacy of the indications of this instrument:—

	I.	II.	III.
Oxygen, ..	20.880	20.888	20.883
Nitrogen, ..	79.120	79.113	79.117
	100.000	100.000	100.000
	IV.	V.	VI.
Oxygen, ..	20.867	20.868	20.776
Nitrogen, ..	79.133	79.132	79.124
	100.000	100.000	100.000

BASFORD'S PATENT METHOD OF PURIFYING GAS.

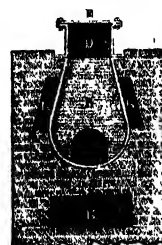
—BASFORD obtained a patent in 1855 for purifying gas, by passing it through heated charcoal, previously impregnated with lime-water.

Wood charcoal is preferred, and this is immersed in a saturated aqueous solution of lime, for not less than fifteen minutes, after which it is termed by the patentee *prepared charcoal*. The apparatus in which this is heated, and in which the gas passes over the charcoal, is of cast-iron, and is represented in Figs. 128, 129, and 130. It is divided into separate compartments, *AA*, by

Fig 128.



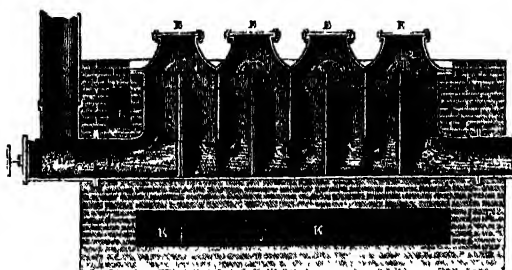
Fig. 129



partitions alternately fixed and loose, the former being shown by *B*, while the latter are indicated by *C*. Figs. 129 and 130 exhibit these more in detail. Each fixed partition has an opening—Fig. 130—at the bottom,

while those which are movable are open at the top, so that the gas can be made to pass alternately up and down the several chambers, *over the loose, and under the fixed diaphragms*. Open covers to the compartments are indicated at D, and are closed by lids or

Fig. 130.



plates, E. To one end of the apparatus is attached a D-shaped flanged pipe, F, into which the pipes leading from the retorts are fixed, either vertically by the pipe I, or horizontally by the mouth-piece G, as may be required. The outlet pipe of the apparatus, by the hydraulic main, and thence to the gas-holder, is seen at H. K K are flues, by means of which heat is applied, and L L designates the brickwork in which the whole apparatus is set.

On the gas passing through the heated prepared charcoal, it is freed from a large amount of foreign compounds, partly by chemical, partly by mechanical action, and deposits a residuum, which possesses the properties of, and may be used as, a pigment. The gas thus purified has a much greater illuminating power than that submitted to the ordinary process of depuration.

The claim of the patentee is—1. For the separation of the impurities from coal-gas, by passing it through charcoal saturated with lime-water, and heated as described; and, 2. For the formation of a residuum, or deposit, derived from the gas, which may be used as a pigment, or color.

For the removal of the ammonia and the sulphide of hydrogen by one and the same process, a new method of purification has been adopted, and is one well worthy of confidence. The screens of the purifiers are covered with a mixture of carbonate of lime and sulphate of iron, which, subsequently exposed to the air, become carbonate of iron and sulphate of lime; and by the absorption of oxygen, the carbonate of iron leaves its carbon, and becomes partly sesquioxide of iron. The gas, streaming through this mixture—sesquioxide of iron and sulphate of lime—gives up its sulphide of hydrogen to the oxide of iron, forming sulphide of iron and water, while the carbonate of ammonia—contained also in the impure gas—decomposing the lime-salt, forms sulphate of ammonia and carbonate of lime.

When the purification is completed, and the mixture has done its work, it is exposed to the air, and the sulphide of iron absorbing oxygen, is converted into a basic sulphate of iron. Hence, the same mixture as at first is obtained, namely, carbonate of iron and sulphate of lime, with the addition of sulphate of ammonia, which may be washed out and preserved, while the

residue is employed over and over again. By this elegant process, the noxious sulphur compounds are utilized in the fabrication of sulphate of ammonia, and the mixture seems never weary of performing its duty; hence, not only is the februation performed at one process, but the noxious ingredients are converted into compounds of much value.

Another method of removing ammonia may be noticed: it consists in spreading on the screens superphosphate of lime, consisting of bones decomposed by sulphuric acid; the addition of ammonia to this, makes it a powerful and excellent manure.—*Clegg*.

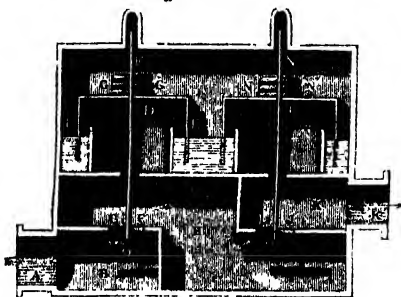
CHISHOLM'S METHOD.—CHISHOLM'S method for the purification of gas consists in combining or mixing together the peculiar red earthy or ochry-looking substances found mingled with peat and the subsoil of peat, with hydrate of lime, or the mixed hydrates of lime and magnesia obtained from magnesian limestones, and their combination or mixture. He then introduces into the vessel, known to gas-makers as the dry-gas purifier, this mixture, and the foul gas passes through it until it is rendered pure; such purity being ascertained by the application of the tests usually employed by makers of gas for that purpose. The red earthy or ochry substance above alluded to, is composed chiefly of the oxides and salts of iron and manganese, and it is principally to these metallic matters that the purifying agency of the compounds is due; therefore, the greater the quantity of these oxides this earthy matter contains, the better is it adapted to the purpose for which the patentee uses it; and although the exact proportion of lime to be added is not material, yet the greater the amount of metallic matters there may be contained in the red or ochry earthy matters aforesaid, the more lime, or lime and magnesia, must be used; for every three parts by weight of metallic matters in this earthy matter, one part of lime by weight is preferred. Instead of the above red earthy matter, there are sometimes employed in the same way and proportion, the fine red sandy gravel so general around London in the neighborhood of chalk beds, or the red clay which is so common around Rugeley and other districts, or the phosphate or subphosphate of iron, known by these names to all geologists, and common in many boggy districts. All these, or any of them, he uses precisely in the way or combination described with respect to red earthy peat matters already alluded to; and he adds, that when these substances or mixtures, or any of them, have ceased to purify the gas from sulphide of hydrogen and other impurities, their powers may be again in part or altogether renewed or restored by passing or forcing through them a current of air, or by merely exposing them to the atmosphere, after which they may be used over and over again, or many times in succession.

POOLE'S PATENT.—POOLE took out a patent for improvements in regulating the flow and pressure of gas and other fluids. He remarks, that it is often desirable to deliver aeriform fluids at a certain uniform pressure, and various means have before been resorted to for effecting this object; accordingly his invention consists of combining the use of two or more governors or regulators, which, acting independently and in succession, are alleged to accomplish the desired object more completely

than has been done heretofore. The description of governors or regulators which are preferred for this purpose, are those where inverted vessels are used, working in quicksilver or other fluid, and connected to the induction valves. Supposing the apparatus to be arranged for regulating the supply of gas or other aeriform fluid, the main or supply pipe, where the regulation is to take place, is arranged to communicate in succession with two or more chambers, each having a governor or regulator, and so that no gas can pass from the main or supply-pipe to the furthestmost chamber, without having passed through, and been regulated more or less perfectly by, the previous regulators or governors; by which means the gas, supposing it to come up to the first governor or regulator at a pressure exceeding that at which it is desired to deliver it at, will act on the governor, and tends to close the valve, and thereby restrict the passage of the gas into the first chamber; the gas then passes from the first chamber or governor into the second, and, if it be still at an excessive pressure, it will be again retarded in its passage, and so on, according to the number of governors or regulators combined and caused to act in succession.

Fig. 131 shows a vertical section of an apparatus combined according to this patent, having two regulators or governors acting in succession; but other apparatus may be made with more than two, to act in succession in a similar manner. The form of regulator or governor preferred, is that where an inverted vessel is employed fixed to the valve, the action of which is to be regulated; but the form of the parts may be

Fig. 131.



varied, so long as two or more regulators or governors are combined to act in succession. No claim, however, is made to the governors or regulators separately, when two or more are not combined to act on and regulate the same supply. A is the inlet for the gas or aeriform fluid; B is a chamber, the opening, C C, out of which is capable of being more or less closed by the valve, O, which is on the stem, F, to which the inverted vessel D is fixed, the edges of which dip into mercury or other suitable fluid at E E; there being weights, G G, on the vessel D, according to the degree of pressure it is desired to regulate or bring the supply of gas or other aeriform fluid to, when it passes away at the outlet, K. The gas or other aeriform fluid coming into the chamber, B—above the desired pressure—will, to some extent, be regulated by its acting on the first regulator by raising the vessel, D, which will also raise the valve, O, in the compartment, B,

towards the opening, C C, till the quantity of the gas allowed to pass into the chamber, H, of the apparatus will be brought to nearly the desired pressure. The gas or aeriform fluid in the chamber, H, passes through the opening, J J, into the compartment, K, and acts on the inverted vessel, L, which is affixed to the stem, N, by which the valve, O, in the chamber, H, will be more or less closed, according as the pressure of the gas or aeriform fluid in the chamber, H, is more or less in excess of the pressure at which it is desired the gas or aeriform fluid should go off at the outlet, K. It would be well to state, that usually the same amount of pressure or weight, N N, is applied to the inverted vessel L, as there is by the weights, G G, to the vessel D, such being believed to be the best mode of working when using such apparatus. The vessel L, like the vessel D, dips into mercury or other liquid at its lower edges. By using a succession of regulators or governors, any want of correctness of the regulation of the first will be compensated for by the succeeding ones.

MICHAEL'S PATENT.—GEORGE MICHAEL, who has also taken out a patent for improvement in the manufacture of gas, remarks in his specification, that in the present state of progress in the different arts which co-operate together in the construction of gas-works, he thinks the power of the manufacturer may be increased, and the gas produced more economically than by the present mode, without employing large numbers of fine strong men to destroy their health, by charging red-hot retorts, through very narrow apertures, with small quantities of coal, and to perspire during twelve hours in front of an intolerably hot radiating surface. He proposes to substitute for the sinews of these men the action of steam-power; and, with this intention, he amplifies considerably the usual dimensions of a retort, in order to obtain in one distilling apparatus as much, if not more, heated surface as is now to be found in a whole bed of sixteen retorts twenty feet long; this he does for the purpose of having the floors of huge retorts all upon one and the same level, in order that the same steam apparatus used for charging and drawing one of them may perform the same operation for the others, by simply moving such apparatus upon rails in front of the retorts.

The dimensions in the clear which he prefers giving to these huge retorts are thirty feet in length, two feet in height, and about nine feet in width, the top being parallel to the floor, so that the transverse section of the interior of the retorts represents an elongated rectangular figure. These retorts are built with fire-bricks; but he observes, that if he only cemented the bricks together with fire-clay, as is usually done, the working of the retort would depend on the regular action of the exhauster—that is to say, that should the exhauster cease to work, the gas would pass through the joints of the bricks, an occurrence which would place a gas-work in jeopardy. To meet this great difficulty, the bricks of which the retort is made are laid in a vitreous cement, which, when subjected to the heat necessary for making gas from coal, forms a glaze, and renders the retort impermeable to gas. The best way to prepare this compound is, to pound and carefully mix together a double, treble, or a more compound fusible

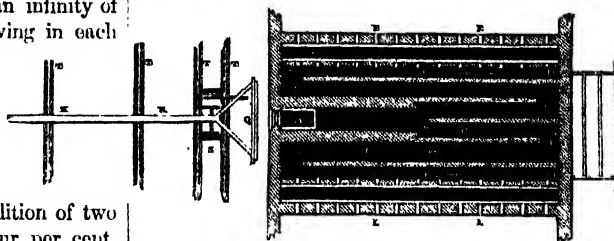
silicate, in which silica, lime, potassa, soda, magnesia, oxide of iron, oxide of manganese, or biborate of soda, may be usefully employed; but should local circumstances not admit of this, the good effect produced by potassa, soda, or better, biborate of soda, in the composition of the cement intended to become vitrified, must not be lost sight of. It is evident that this cement must be formed into a paste with a small quantity of water, so as to be easily used by the bricklayer.

It will be obvious to all practically acquainted with the manufacture of porcelain, earthenware, or glass, that the idea of setting the bricks of the retorts in a vitreous cement can be carried out in an infinity of different ways, according to localities, giving in each place the preference to the cheapest of the articles here above noticed. For instance, in London, and in many other towns, recourse can at once be had to a compound silicate, which is a refuse from the glass paper manufactories—namely, the glass dust—to which an addition of two per cent. or more of manganese, and four per cent. or more of borax, can be made to facilitate the fusion of the aforesaid glass dust. In other places it may be cheaper to employ potassa or soda as a cement between the bricks, the silica and alumina of the fire-bricks, when heated, combining with the alkali and forming a vitreous glazing cement, and so on in a variety of other ways.

MICHAEL'S huge retort is furnished at each end with a cast-iron mouth-piece plate, contrived for receiving a luted lid, which is firmly secured by cotters. This retort is provided with two or more orifices at the top, by which the charge of coal is introduced by tilting waggons running on proper railways; the coal so introduced into the retort is then spread equally over the bottom by the aid of a rake, which forms the head of a rack worked by a steam-engine. The charge of coal preferred to work off in such a large retort is six tons, forming a layer of ten inches deep. When the charge is worked off, the mouth-pieces are to be opened by unfastening and hoisting the lids, and the charge of coke is pushed out in one cake by the assistance of the steam-rack, the head or rake of which being for this purpose turned upside down, so as to act with its head and not with its teeth. Such coke, if it be desired, may be received in an oven capable of being closed, and there treated with this intention by the admission of air and an injection of steam, leaving one opening for abducting the products. One great peculiarity in the construction of these huge retorts is, that they are well isolated from contact with any of those parts of the construction which are liable to cool, either by radiation or by contact with the soil; this isolation is obtained by preserving round the retorts a circumambient empty space, in which the products of the combustion in the fire-places are caused to decant their heat at different stages in their perambulation, before finally passing under the immediate foundation of the retort on their way to the main flue, which is constructed outside the foundations of the retorts, or nearly so.

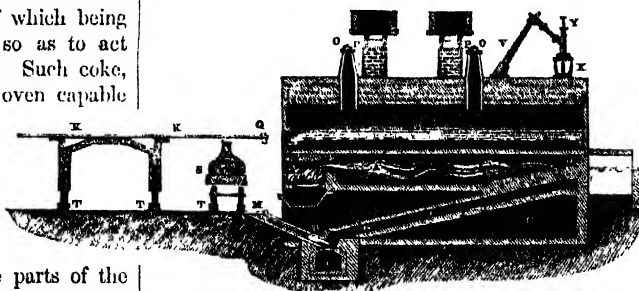
The patentee then proceeds with the technical description of the construction of a retort, such as that referred to in the drawings—Figs. 132 and 133. The products of combustion, on leaving the fireplace, divide into two parts, at B and B'; one follows the course, B, C C C, till arriving at the vertical flue, D, through which it descends into the chamber, F, which is common to these, and to those products of the combustion which have followed the course, B', C' C' C', D'. During such course, the products of combustion emit part of their

Fig. 132.



heat from the orifices, E E E E, through which they ascend round the retort, so that in reality, by this phenomenon of decantation, there are formed two inverse currents on the sides of the retort, the hottest ascending, which, after having parted with a portion of its heat, will become descending; and the constant repetition of these effects will have for result the keeping of the sides and top of the retort at the same temperature as its floor or bottom. The drawings show distinctly how the under floor, the sides, and the top of the retort are constructed, for allowing this phenomenon of decantation of heat to produce its full effect everywhere round the retort. Particular stress is laid on this system of construction, which offers every possible facility to the working out of that law of nature, according to which the hotter parts of the gaseous products have a tendency to rise, and the colder to descend. It is according to the same principle that the products of combustion left in the chamber, F, are caused to descend along an inclined

Fig. 133



plane in the six flues, C G, before entering the lower chamber, H, which delivers them through one aperture to the horizontal chimney, I. The orifice last spoken of is commanded by the damper, R, which regulates the draught of the fireplace. This damper is worked in an inclined flue, the entrance of which is to be covered by the tile, M, in front of the retort. The six inclined flues leading to the

chamber, H, are connected together sideways by the openings, J J.

The under floor of the retort is composed of three parts, differing one from another in their construction—that is to say, the floor of the retort, which is formed by bricks on edge, is separated from the fireplace by an arch of nine inches thickness, from the subsequent main flue by an arch of four inches and a half, and from all the divided flues by flat bricks two inches and a half thick, and eight inches long, laid in six parallel rows, the joints of such rows corresponding to the centre line of five rows of pillars.

Charging and Drawing of Retorts.—The interior of retort, N, receives the charge of coal through the openings, O O, which are shut by luted caps, P P, movable at will; the coal is brought to the retort-house in trucks, so arranged that when tilting their contents fall at once into a movable funnel placed for the time being in the openings, O; these dispositions are required for charging the retort quickly; and, when well adapted, as indicated in the accompanying drawings, the retort can receive its charge of six tons of coal in less than six minutes, provided that the coal be spread at the rate it falls down by proper mechanical power. The apparatus to which preference is given for producing this effect is composed of a cast-iron rake, Q, which forms the head of a rack sliding in a cast-iron frame, K K; this receives its motion from a steam-engine, S, fitted to the frame; the motion is transmitted by the ordinary mechanical contrivances. In order that the same steam apparatus may be rendered serviceable for the working of twenty-four retorts, or more, the frame here spoken of rests upon a system of wheels, T T, rolling upon rails parallel to the front of the retorts. The steam is adducted by a pipe which runs in a casement surrounded by sand or other non-conductor, the full length of the beds of retorts; this pipe is provided with small outlet branches and cocks between each two retorts, for the purpose of delivering the steam to the engine of the steam-power rake, through a movable connecting pipe. When the gas is worked off, and the charge is ready to be withdrawn, the lids of the retorts are moved, and the coke is pushed out of the retort in one lump by the action of the steam-rake, the head of which—namely, the rake—is for that purpose turned upside down by swivelling it round a collar. By this contrivance the teeth of the rake are spared, and its head, which is shaped like a strong rib, performs the work of clearing the retort. It is well to observe, that, in order to prevent the teeth or the rib of the rake wearing out the brickwork, they are kept at half an inch distance from the floor or bottom of the retort by friction rollers, suitably placed for bearing the weight of the apparatus. There are also friction rollers fitted on the sides of the rake for guiding its movement along the sides of the retort.

When the retort is at work, the gas passes off through the ascension pipe, V, and enters the hydraulic main, X, through the plunger, Y, which is suspended to a screw, and can be moved up and down for the purpose of transforming at pleasure the hydraulic main into a dry main by suppressing the dip, which contrivance is very valuable for relieving the retorts from all pressure.

Mr. ALEXANDER CROLL has taken out a patent for freeing gas from its ammonia, and a part of the sulphide of hydrogen, producing at the same time chloride of ammonium. He introduces a solution of the chloride of zinc into a vessel, upon the same construction as a wet lime purifier; on admitting the gas, double decomposition ensues; an insoluble sulphide of zinc, and a solution of chloride of ammonium, are produced. The gas must be further purified with lime in the usual way.

The specifications of a great number of other patents for alleged improvements in gas-making might be given; but as they are not of much interest, and probably of too little usefulness ever to be adopted, the Editor deems it unnecessary further to allude to them, which would only exhaust the patience of the reader with a series of dry details. In conclusion, the Editor has to express his thanks for the courtesy and information rendered to him by Mr. SAMUEL EDWARDS, formerly of the Liverpool Gas Works.

GELATIN.—*Gélatine*, French; *Gallerte*, German; *Gelatin*, Latin.—Skin, the tissue of bones, cartilages, and many analogous animal tissues, possess the well-known property of yielding to boiling water a substance capable of becoming jellied by the cooling of the menstruum. This was for a long time regarded as a peculiar organic principle, and was known by the name of *gelatin*; but, latterly, MÜLLER found it to consist of gelatin, properly so called, and of another particular product, which he denominated *chondrin*. It is generally assumed, though not perhaps on very sufficient grounds, as BRANDE remarks, that the gelatinous textures do not contain ready-formed gelatin, that that substance does not, in fact, pre-exist in the animal kingdom, but that it is generated by the action of hot water upon the membranous tissues.

The historical information connected with this subject is very limited. *Ichthyocolla*—the Latin synonym for *isinglass*, derived from two Greek words, signifying *the glue of fish*—is repeatedly mentioned by DIOSCORIDES and PLINY; the latter writer attributes the discovery of it to DÆDALUS.

PREPARATION.—Gelatin is obtained by subjecting fragments of hoofs, horns, hides, bones, the feet of calves, cows, sheep, *et cetera*, to the action of boiling water or steam. The resulting menstruum is skimmed and strained, so as to effect the removal of floating fatty bodies, and of any deposit which might be formed; then allowed to gelatinize by spontaneous decrease of its temperature.

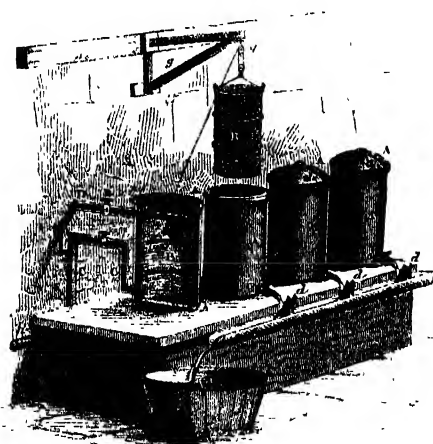
It may also be procured from shavings of hartshorn, the product being tasteless, and having the advantage of being entirely free from fatty and oleaginous matters.

When gelatin is used as an article of food, the material should be of the best description, and quite fresh. Bones intended for this purpose ought to be well preserved in brine, or to be dried in a stove. Their gelatin is best extracted by the combined action of steam and a current of water percolating the fragments. Cast-iron cylinders are generally used in this part of the process. A vertical section of one of these is represented in Fig. 134, where A A A show the exterior cylinders, containing a basket or cage, B, filled with

bruised bones; *c c* the pipe conveying steam to the interior; *D*, a pipe for the introduction of water, provided with a stopcock, *E*, for regulating the quantity of the supply, and to which is accurately fitted a tube of tinplate, *F*, closed at the inside end, and perforated on its under side with small holes, so as to allow of the percolation of the water: this tube is inserted in its proper place after the bone-cage has been introduced.

The cylinders, represented by *A A A A*, are elevated about twenty inches from the floor, and secured in their respective positions by screws; *a a* are the lids, in which are tubulures or valves; a thermometer is placed at *b*; the stopcocks, for withdrawing the gelatinous menstruum, are shown at *cc*; *d d* are small

Fig. 131.



gutters of tinplate; *cc*, the main conduit of discharge into the cistern, *f*; *g g*, blocks and tackle for raising the bone-basket; *h*, the main steam-pipe.

When a pure jelly is required, the cylinder, after being charged with bones, is wrapped in a strong, coarse woollen material; as soon as the fatty matters cease to flow, the stopcock, *E*, which admits the cold water, is closed, as also those at the bottom of the cylinders, *ccc*, which are to be opened only at the end of every hour, but to such an extent only as to let the gelatinous solution run out, without allowing any steam to escape. The menstruum is subsequently strained, and poured into shallow vessels of tinplate, or upon slabs of marble, slate, or compact and polished stone, to solidify. It is finally cut into shreds, *et cetera*, as may be thought proper. This is, however, only one method of manufacturing gelatin; and others, for which patents have been obtained, will be given in a subsequent part of the present article.

PROPERTIES.—When *pure*, gelatin is colorless, transparent, hard, and endowed with great but variable coherency, according to the kind of tissue from which it is obtained. It is inodorous and insipid. Its specific gravity is greater than that of water. It has a neutral reaction. When heated, it softens, diffuses a peculiar odor, enters into a state of semi-fusion, bends, tumefies, and then exhales the odor of burnt horn. In the air it takes fire with difficulty, smokes, flames only some

instants, and leaves a bulky charcoal difficult to incinerate, the ashes of which consist principally of phosphate of lime. By dry distillation, gelatin gives much carbonate of ammonia, and yields in general the ordinary products of the distillation of nitrogenized substances.

In cold water it softens, intumescs, becomes opaque, but does not dissolve. A liquid which contains one-hundredth part of its weight of gelatin becomes viscous on cooling, but when it has only the one-hundred-and-fiftieth, the menstruum remains fluid. These phenomena, however, vary with the temperature. In winter the jelly is much more readily formed than in summer. If the solution of the gelatin is effected too quickly, the jelly obtained is less firm. Moreover, the result varies, not only in gelatin obtained from different tissues, but also with that obtained from the same tissue taken from animals of various ages.

It differs also according to the care which has been taken in the preparation of the gelatin; when its solution has been exposed to a temperature higher than 212° ; and when it begins to sour, it loses in part the property of becoming jellied. The same happens when its solution is heated and cooled several times. If gelatin be left a long time in the open air, at a temperature of 60° to 68° , it becomes ammoniacal, and putrefies, diffusing a very fetid smell. The addition of a certain quantity of acetic acid prevents the putrefaction without destroying its adhesive power.

Gelatin is not sensibly soluble in alcohol, and when the latter is poured into its solution, lukewarm and somewhat concentrated, it coagulates in a white coherent, elastic, and slightly fibrous mass, which adheres to the vessel with much force. Like dry gelatin, it softens in cold water without dissolving in it. On evaporating the alcohol, there remains a thin transparent coating, very soluble in cold water, but which is not capable of being jellied. Common gelatin, in a dry state, treated with alcohol, gives up to it a certain quantity of fatty matter, and some substances of an extractive nature. It is perfectly insoluble in ether and in oils, both fat and volatile.

Gelatin, when in the jellied state, and treated with alcohol, undergoes a dehydration, under the influence of which it contracts much. It was by this means that GONNOR succeeded in remarkably reducing the size of a print obtained in a very hydrated film of gelatin, and transferring it, so reduced, to stone, from which he obtained a new impression, quite similar to the first, but more or less diminished.

By taking these prints, on the contrary, with gelatin very little hydrated, and afterwards steeping them in water, a dilatation of the plate is obtained, which enlarges the figures with the same regularity.

THENARD observed, that if chlorine be passed into a somewhat concentrated solution of gelatin, each bubble is surrounded with a white elastic matter, which follows it to the surface of the liquid, and which, at the moment when the bubble bursts, leaves a white glutinous matter, capable of taking a chatoyant appearance by malaxation. Only a small quantity of chlorine is required to precipitate all the gelatin, and, when this body is in excess, the deposit becomes of a light yellow, the liquor containing free

hydrochloric acid, and only a very small quantity of animal matter remaining in solution. Gelatin, combined with chlorine, is insoluble in water and alcohol; it reacts as an acid, a property of which it may be deprived by macerating and washing it with tepid water. It exhales the odor of chlorous acid, which it evolves when heated at 212° , a brownish residue remaining. MULDER states that it consists of one equivalent of gelatin $= C_{18} H_{10} O_6 N_2 + Cl_2 O_3$. When acted upon by ammonia, nitrogen is disengaged, chloride of ammonium formed, and unaltered gelatin separated. An opalescent, gelatinous body is simultaneously produced, the composition of which is represented by the last-mentioned chemist as three equivalents of gelatin $= 3(C_{18} H_{10} O_6 N_2) + 2(Cl_2 O_3)$. MULDER has also examined two additional chlorous compounds of gelatin, the first being $4(C_{18} H_{10} O_6 N_2) + Cl_2 O_3$; the other, $5(C_{18} H_{10} O_6 N_2) + 2(Cl_2 O_3)$. Much doubt exists with regard to the correctness of these results. Iodine and bromine do not give rise to any synonymous combinations.

Concentrated sulphuric acid produces a very remarkable alteration in gelatin, converting it into *sugar of gelatin, leucin, &c.*, which will be subsequently noticed.

Nitric acid, aided by heat, transforms gelatin into oxalic acid.

Concentrated acetic acid renders softened gelatin transparent, and then dissolves it; the solution does not become viscid, but preserves its adhesive property. Diluted acids, on the other hand, do not prevent gelatin giving a coagulum on cooling.

The alkalis when dilute, and even concentrated ammonia, do not deprive it of the property of becoming jellied, but render the solution turbid by causing a precipitate of phosphate of lime. Softened gelatin dissolves at the ordinary temperature in concentrated aqua potassæ, leaving a white residuum, which is composed principally of phosphate of lime. If the solution be exactly saturated with acetic acid, and evaporated, it does not become glutinous; the gelatin, altered and combined with acetate of potassa which remains after the evaporation, is soluble in alcohol. Sulphuric acid precipitates from this menstruum sulphate of potassa, combined with modified gelatin; and if the precipitate be dissolved in water, and the liquor left to spontaneous evaporation, it crystallizes to the last drop. The aqueous solution of the salt is abundantly precipitated by the infusion of nut-gall, by chloride of mercury, and by the sesquisulphate of iron. Hydrate of lime does not alter the solution of gelatin, which dissolves much of it. The same may be said of phosphate of lime; hence the reason why so large a quantity of this salt occurs in the glue of commerce. No subsidence is occasioned in dissolved gelatin by the addition of neutral sesquisulphate of iron, until the menstruum has been boiled, when a flocculent reddish-yellow precipitate falls, consisting, according to MULDER, of three equivalents of gelatin combined with six equivalents of oxide of iron, and one of sulphuric acid. DUMAS states that gelatinous menstrea are not thrown down either by the neutral or basic acetate of lead, but, according to GMELIN, the latter causes the forma-

tion of a copious subsidence. If a gelatinous menstruum be gradually mixed with a solution of chloride of mercury—corrosive sublimate—a cloudiness is produced which quickly disappears. This effect continues till a certain quantity of the reagent has been added, when the gelatin is at once precipitated as a white, coherent, and very elastic coagulum. The behavior of gelatin with nitrate and subnitrate of mercury is synonymous. Protochloride of tin causes a brown flocculent subsidence, but the bichloride gives no reaction.

Silver and gold salts do not precipitate gelatin, but by the influence of solar light a portion of the metal is reduced. It is thrown down by sulphate of platinum in brown viscous flakes, which blacken on the filter, and are afterwards easily pulverized. E. DAVY regards this salt as an infallible test for the detection of gelatin, even in the presence of albumen, and in solutions so dilute as to be unaffected by tannic acid.

Tannic acid is a valuable and delicate test of the presence of gelatin. When added to a solution containing only one-five-thousandth part of gelatin, nebulosity is immediately apparent. When more concentrated gelatinous menstrea are treated with tincture or infusion of galls, a dense, white, caseous subsidence occurs, which, on desiccation, becomes brownish-yellow, agglutinates, and forms a hard, brittle mass, easily reduced to powder.

From the investigations of MULDER, it appears that several definite and permanent combinations of gelatin with tannic acid are capable of being formed. On combining the pure solutions of these bodies, a neutral combination, containing one equivalent of gelatin, one of tannic acid, and two of water, is formed. According to DAVY, the compound of gelatin with oak-tannin consists of—

	Centimally.
Gelatin,	54
Tannic acid,	46
	100

M. SCHÉBEL, who obtained nearly the same results, says that one hundred parts of gelatin precipitated with a large excess of a solution of extract of oak-bark in nine parts of water, combined with 118.5 parts of tannic acid. When, on the contrary, he mixed a very dilute solution of extract of oak-bark with the solution of gelatin, without precipitating the whole of the latter, the deposit, which occupied a considerable time in subsiding, contained 59.25 per cent. of tannic acid. The gelatin was combined, in each of these cases, with different proportions of tannin, which are to each other as 1.0, 1.5, and 2.0.

Gelatin, says DUMAS, unites with various quantities of tannins derived from other sources, but never to a less extent than sixty per cent. when the precipitated menstruum contains tannin in excess.

It would sometimes be important, in researches relative to animal chemistry, to be able to separate tannin from gelatin, but this has not been effected. A dilute solution, either of caustic alkali or a carbonate, extracts much of the tannic acid, and leaves a gelatiniform, mucilaginous, swollen mass, which, with the aid of heat, dissolves in alkali like gelatin; but it is found in this case, that the solvent employed for

removing the tannic acid has also taken up a certain quantity of gelatin, and if the mass in question be digested with water, a little of the gelatin dissolves out, while the remainder is converted into that combination of gelatin and tannin which has been already mentioned as so slow in depositing.

COMPOSITION.—Ultimate analyses of gelatin have been made by numerous chemists, but with different and ill-agreeing results, the foremost among them being those of MULDER, SCHERER, and GOUDER: the formulæ proposed to represent its composition are, consequently, equally diverse. That, however, adopted by LÖWIG appears to approach nearer to the atomic combinations which have been examined, and to agree better with experiment than any other, and is adopted in the following tabulation:—

	Centesimally represented				
	At weight	Theory.	Mulder.	Scherer	Goudover.
13 Eqs. Carbon,...	78	50.00	50.04	50.78	50.00
10 Eqs. Hydrogen,...	10	6.41	6.47	6.9	6.72
5 Eqs. Oxygen,...	40	25.64	25.13	23.8	23.75
2 Eqs. Nitrogen,...	28	17.95	18.36	18.9	18.32
1 Eq. Gelatin,...	156	100.00	100.00	100.0	100.00

Sugar of gelatin, to which allusion has already been made, was discovered by M. BRACONNOT. This chemist triturated one part of pulverized gelatin with double its weight of concentrated sulphuric acid, and set the mixture aside for twenty-four hours. At the end of this time the color of the liquid was not deepened. He then added eight parts of water, and subjected the menstruum to ebullition for another twenty-four hours, keeping up the quantity of water. On diluting the fluid, saturating with carbonate of lime, filtering and evaporating, a sirup was produced, which, when allowed to remain quiescent for a month, deposited granular crystals strongly adherent to the bottom of the vessel. These were edulcorated with weak alcohol, and purified by repeated crystallization.

Sugar of gelatin possesses a marked saccharine taste, very nearly allied to that of grape sugar. It is soluble in water, but not in alcohol. An aqueous solution, if kept in admixture with yeast, exhibits no sign of fermentation. According to BOUSSINGAULT, the aqueous solution of gelatin sugar gives no precipitates with sulphate of copper, acetate of lead, or the nitrates of mercury and silver.

Nitric acid decomposes sugar of gelatin, giving rise to a peculiar compound, which BRACONNOT designated *nitrosaccharic acid*, but which it would be useless to describe here.

The composition of sugar of gelatin is as under:—

	Centesimally		
	At weight	Theory	Mulder
8 Eqs. Carbon,.....	48	34.04	34.06
9 Eqs. Hydrogen,.....	9	6.38	6.49
7 Eqs. Oxygen,.....	56	39.72	39.61
2 Eqs. Nitrogen,.....	28	19.86	19.84
1 Eq. Crystallized } gelatin sugar, }	141	100.00	100.00

Leucin, previously mentioned as being one of the products of the decomposition of gelatin by sulphuric acid, has been shown by MULDER to be formed also during the putrefaction of casein.

Leucin has a pearly lustre. It is friable, tasteless, inodorous, and greasy to the touch, and sublimes before fusion at about 310°. It is soluble in about twenty-eight parts of water at 65°, and in six hundred and fifty-eight parts of alcohol, of specific gravity 0.828, at the same temperature. A saturated alcoholic solution becomes turbid on cooling. It is insoluble in ether, and is anhydrous, and neither acid nor alkaline.

Further, leucin, as BRANDE states, is soluble without decomposition in concentrated sulphuric and hydrochloric acids. Chlorine decomposes it, forming hydrochloric acid and other products, among which is a brown resinoid substance, and a red volatile fluid. It absorbs hydrochloric acid gas, forming with it a mono-atomic combination. Its composition, as determined by MULDER, is as follows:—

	Centesimally		
	At weight	Theory.	Mulder.
12 Eqs. Carbon,.....	72	55.39	55.53
12 Eqs. Hydrogen,.....	12	9.23	9.22
4 Eqs. Oxygen,.....	32	24.62	24.74
1 Eq. Nitrogen,.....	14	10.76	10.51
1 Eq. Leucin,.....	130	100.00	100.00

USES.—Gelatin is employed for making jellies and blanc-manges. Considered medicinally, it is emollient and demulcent, and for this end is dissolved in water or milk, and rendered palatable by the addition of acid and sugar. Latterly, it has come into considerable use in pharmacy for the formation of capsules intended to conceal the nauseous odor and taste of medicinal preparations enclosed in them. It has likewise been used for coating pills, and certainly offers advantages not to be derived from the now almost obsolete practice of covering them with gold leaf. In the laboratory it is employed as a test for tannic acid.

PATENTS.—Numerous patents have been taken out for the manufacture of gelatin. Several of these are of importance, and will be briefly noticed.

In 1839, a patent was granted to GEORGE NELSON for improvements in the preparation of gelatin. The products of the process are of two kinds, which the patentee denominates as gelatin of the first and second quality. The best sort is opaque, and is by preference made from cuttings of the hides of beasts or of the skins of calves. The inferior variety is procured from *glue-pieces*, freed from hair, wool, and fleshy and fatty matters. The *modus operandi* is essentially the same in both cases, and is as follows:—The cuttings being well washed are macerated in caustic alkali at a temperature of 60°, until they are partially softened. Ten days is the period named as required to effect this. They are then placed in close vessels, and permitted to remain until a thorough softening—ascertained by passing a fork through them—is effected. They are now washed in a revolving cylinder, through which a current of water passes; exposed in a well-closed chamber to the action of sulphurous acid; submitted to pressure to remove the adhering water; and subjected to the action of steam at about 150°, till they are, as far as possible, dissolved. The menstruum is then strained, and set aside at a temperature of 100° to 120°, for the impurities which may have remained to subside; then

poured upon slabs of slate or marble to the depth of about half an inch, and allowed to remain there till it has sufficiently solidified, when it is cut, and washed to remove all traces of acid. It is subsequently redissolved by means of a steam-bath at the temperature of 85°, and finally re-solidified, and exsiccated by exposure to dry air upon nets.

C. R. ROPER, for whom a patent was sealed in April, 1845, prepares gelatin from bones or ivory, broken into small pieces in a digester. To each hundred-weight of material is added six gallons of water, and the vessel being closed, steam is admitted at a pressure gradually raised to thirty-two pounds per square inch for three and a half hours, when the charge is withdrawn. If the bones were in a pulverulent state, it would be requisite that the gelatin should be pressed out from the residuum; but if they were merely broken into fragments, this would not be necessary. The product is now run into shallow tins or pans to solidify, and finally placed on nets to dry in the usual manner.

The specification also includes the flavoring of the gelatin with essences of lemon or almonds, for the preparation of jellies or blanc-manges.

In 1846, ARNEY took out a patent for the preparation of gelatin in powder, and free from water, so that it is not so liable to become mouldy, while it is reduced to such a state that it readily dissolves in water upon the application of heat. Ordinary gelatin is subjected in a stove-room to a temperature which ranges from 150° to 212°, and when the moisture is entirely dissipated, it is broken to pieces, and ground, in a mill of any ordinary kind, to a fine powder. The patentee claims, secondly, the application of gelatin in a powdered state, by means of a particular method of sweetening and flavoring, from which jellies may be prepared by dissolving it in water, and blanc-manges by infusing it in milk. He also applies his powdered gelatin, when mixed with farina or starch, or starch vegetal flour, and flavored with essence of meats, culinary herbs and spices, in the way set forth in the specification, for the purpose of thickening, enriching, and flavoring soups, gravies, *et cetera*.

In 1844, Messrs. J. and G. Cox of Edinburgh patented a process, by which they obtain a perfectly pure substance, possessing a gelatinising force superior to that of isinglass.

Shoulders and cheeks of ox hides, which are preferred by the patentees, are thoroughly cleansed in water, after which they are cut into pieces by a machine similar to that used for cutting straw, and then subjected to the action of a paper-maker's pulp-mill. By this process, the gelatinous fibre is well washed and cleansed, as a stream of water flows through the mill during the whole operation, carrying off all the impurities. The material is next pressed between rollers, mixed with fresh water sufficient to effect its solution, and heated to a temperature varying from 150° to 212°. By these means a superior gelatin is speedily produced, and it is said that the gelatinising power is not weakened by a lengthened exposure to heat.

When a very pure product is desired, the grain and flesh are removed as completely as possible from the hide pieces, the albuminous matters being thus separated.

After that portion of the process already noticed has been gone through, the liquid gelatin is placed in a steam-bath, and when heated to a temperature not exceeding 160° or 170°, fresh ox blood is added, in the proportion of one gallon to seven hundred of the gelatin. As the temperature increases, the albumen of the blood becomes coagulated, partly rising as a scum to the surface of the menstruum, the other portion descending to the bottom. When the magma has all ascended, the heat is lowered, and it is removed, and the purer liquor allowed to settle for about an hour, when it is run into coolers, where it congeals, and is then cut out into any convenient way and dried, *in vacuo*, by a process similar to that for the evaporation of saccharine menstrua.

By another mode of concentration, the gelatinous solution is run upon a steam-heated surface—say pipes of half an inch diameter, placed within one-eighth of an inch apart—to the depth of about an inch. The exsiccation is then completed in the open air.

A patent was granted, in 1847, to G. P. SWINBORNE, for improvements in the manufacture of gelatin by the following process:—Hides or skins, or those parts of them known as glue-pieces, are cut into shavings, or thin slices or films, by any suitable instrument; these are then soaked in water, which is changed two or three times each day, until no smell or taste can be detected either in the water or in the shavings, which are then removed, subjected to heat with water sufficient to cover them when pressed down in any suitable vessel. The gelatin, thus dissolved, is strained, subjected to slight pressure, and run in thin films upon a smooth surface of slate or other material to set, and then placed on nets to dry in the ordinary way, and finally cut into shreds.

A fish gelatin is also prepared by the same method from cod sounds, which forms a good and cheap substitute for isinglass for clarifying liquids.

ISINGLASS.—*Colle de poisson*, French; *Fischlein*, German; *Ichthyocolla*, Latin.—The repeated mention by DIOSCORIDES and PLINY of *ichthyocolla* has already been noticed.

Isinglass is obtained from the air-bag, or sound, as it is sometimes termed, of various fishes, many of which are still unknown. The finest kinds are produced by species of the *Acipenser*, and some other genera, as the *Morrhua*, *Silurus*, and *Gadus*.

The method of preparing the air-bags for sale, differs considerably, according to the country in which it is conducted. The commercial *pipe*, *purse*, and *lump* isinglass consist of the bag desiccated, but unopened. The *leaf* and *honeycomb* kinds are examples of the bladder cut open and dried unfolded; in the *staple* and *book* varieties, it is folded, while in the *ribbon* isinglass, it is rolled out. It is *picked* or *cut* before importation into Great Britain.

DESCRIPTION.—For a delineation of the various kinds of isinglass, the Editor holds himself indebted to Dr. PEREIRA. The very able dissertation of that pharmacologist on the various fishes from which isinglass is prepared, must, however, be omitted, as out of place here.

1. RUSSIAN AND SIBERIAN ISINGLASS.—The isinglass produced in the Russian empire is principally

obtained from the sturgeons. These cartilaginous fishes constitute the genus *Acipenser*. But this is not the only genus from which isinglass is obtained in Russia, for it is also procured from the *Silurus glanis*, which Dr. ROYLE suggests may be the source of the Samovey isinglass of commerce. BRANDE thus describes the preparation of Russian isinglass:—The swimming bladder is cut open, washed, and then exposed to the air with the inner silvery membrane turned upwards. The latter is then stripped off and placed in damp cloths, or left in the outer covering, and prepared or kneaded. It is then taken out of the cloths, and either merely dried—*leaf* isinglass—and twisted in a serpentine manner, between three pegs, into the shape of a horse shoe, heart, or lyre—*long* and *short staple*—or folded in the manner bookbinders fold printed sheets of paper—*book* isinglass.

Dr. PEREIRA observes in a foot-note to the above account of BRANDE, that though it agrees with the statements given by PALLAS, GMELIN, GEORGI, and TOOKE, there must be some inaccuracy in it. The immersed membrane of the swimming bladder is insoluble, though, according to BRANDE's view, the innermost is the gelatinous membrane. According to T. W. C. MARTIN, the swimming bladders are first placed in hot water, carefully deprived of adhering blood, cut open longitudinally, and exposed to the air, with the inner delicate silvery membrane upwards. When dried, *this fine membrane is removed by beating and rubbing*, and the swimming bladder is then made into different forms.

Several kinds of leaf isinglass, says BRANDE, are imported from Russia. The finest kind is that from Astrakhan, one variety of which is said to be obtained from the Beluga—*Acipenser huso*. These are imported from St. Petersburg. The Samovey leaf is an inferior kind brought from Taganrog. Sisane leaf is the produce of a small fish, each piece measuring only about two and a half inches each way, and weighing about a drachm; it looks like pieces of dried bladder, marked by two fibrous or muscular bands. Kroski isinglass is in small circular membranous discs. Long staple isinglass is of fine quality, and is the produce of the Oural. It is usually imported loose; at times it is strung on ropes, and this latter kind is preferred. Of short staple, three varieties are known: the finest is from the Oural, and is distinguished by the name of Patriarch, but it is very scarce. The Astrakhan short staple is one of the best kinds. The Samovey short staple is of inferior quality. Two sorts of book isinglass are met with; that from the Oural is excellent; but the Samovey product is little regarded. Siberian purse isinglass is of moderately good quality, and is in general demand. A small kind on strings, in a necklace form, is sometimes imported.

2. **BRAZILIAN ISINGLASS.**—This is imported from Para and Maranhão, and, according to GUIROURT, is sometimes denominated Cayenne isinglass. The fishes which produce it are not known, but it is obvious, from a superficial examination of the commercial specimens, that they must have been obtained from at least several species or genera. YARREL suggests the genera *Pimelodus* and *Silurus* as the sources of it.

It comes over in the form of *pipe*, *lump*, and *honeycomb*.

Pipe Brazilian isinglass must have been procured from a large fish. It is prepared by drying the swimming bladder unopened, and in some cases this is found distended with air. Each air-bag or *pipe*, as it is called, is from ten to twelve inches in length, and two or two and a half inches broad, weighing about five ounces, in shape somewhat conical, tapering at one extremity, but broader at the other, where on each side is a caecal prolongation. It is devoid of smell. Lump Brazilian isinglass consists of two swimming bladders placed side by side, considerably separated at one end, but communicating with each other at the diverse extremity. When perfect, each specimen bears some resemblance to that of a torpedo. A perfect, though not very large lump, measured eight inches in length, and at the greatest latitude, five inches. Its weight is about six and a half ounces. It consists of three portions, separated by constrictions. The largest portion is five inches broad, and three and a half inches in length, flattish in front, rounded posteriorly. It consists of two sacs, placed one on each side. The middle portion is oblong, three inches in length, and two in breadth. This is also formed of two sacs, communicating with the preceding portion. The third portion is oblong, one and a half inches long, and three-fourths of an inch wide. This consists of one sac only, into which both sacs of the middle portion open.

Honeycomb Brazilian isinglass appears to be the largest quantity of the lump variety split open. The latter is sometimes softened, and rolled out into thin ribbons, in this country. On account of its deeper color and less solubility, Brazilian isinglass is not in demand for domestic use; though, as it is sold in the cut state, it is probably largely intermixed by shopkeepers with the finer kinds of Russian isinglass, and sold as such. As it is moderately cheap and soluble, it is in extensive use for fining by brewers, who are the principal consumers of this variety. When digested with boiling water, it leaves a large proportion of undissolved white matter of a starchy consistence.

3. **New York Isinglass.**—Occasionally, ribbon isinglass is imported from New York. It is in thin strips of several feet long, and from an inch and a half to two inches in width. It is less soluble than Russian isinglass, and affords a dark-colored solution. Dr. J. V. C. SMITH states that it is obtained from the air-bladder of the common Hake—*Gadus merluccius*—which is macerated in water for a short time, and is then taken out and subjected to pressure between two iron rollers, by which it is elongated to the extent of half a yard or more. It is then carefully dried, packed, and sent to market. The common cod—*Morhua vulgaris*—yields a poorer kind of isinglass; but the hake only is known to the extensive manufacturers as fit for their purposes.

4. **Hudson's Bay Isinglass.**—Dr. PEREIRA was unable to ascertain from what fish this isinglass is procured. It comes over in the purse form. One specimen measured twelve inches in length, and three and a half in diameter; its weight is one ounce and a half. It is of a light yellow color, translucent, and free from

taste and smell. The inner lining of the sac, which may be readily stripped off, is insoluble in water; the remaining membrane dissolves in boiling water.

5. *East India Isinglass*.—It appears that, for a long period, this has been exported from Calcutta to China, but it has only recently occupied the attention of Europeans. It is probably the produce of a species of *Polynemus*. But, according to Dr. ROYLE, the fishes which Dr. BUCHANAN named *Bola*, and several species of *Silurus*, especially *S. raita*, also yield isinglass. Most of the specimens of Indian isinglass examined by Dr. PEREIRA had an unpleasant fishy odor, which rendered them totally unfit for household use, and greatly deteriorated their value for domestic purposes. A sample of East Indian purse isinglass, examined by Dr. PEREIRA, consisted of an unopened swimming bladder, flattened and dried. Its shape is oval-oblong, its length nine inches, its breadth three and a half inches, its weight seven and a half ounces. It has a strong fishy smell, and is of a dark color.

Another kind—East India leaf isinglass—is the sac merely laid open and dried. It is eight or nine inches long, six or seven inches broad, and about three-tenths of an inch thick. A third variety—East India rolled leaf isinglass—which Dr. PEREIRA received from Dr. ROYLE, appears to have been formed by rolling out the preceding kind into thin plates. One specimen was about eighteen inches long, three and a half inches wide, and one-tenth of an inch thick. Some of the sheets are covered with a thin film of chalk.

Picked East India isinglass is in small shreds, two or three inches long, and tapering at the extremities. It is hand-picked in India by the natives.

Manilla isinglass has been imported recently as *thin cake*. It is white and clean, and is equal in quality to Brazilian or Samovey book. The fish which yields it is found in the river of Manilla, and on the coasts of the Philippines, Luconia. It is smaller than the Brazilian, but greatly resembles the lump variety of that kind, and the fish is probably an allied species.

6. *Cod Sounds*.—These, in the dried state, are brought from Scotland, and used as a substitute for foreign isinglass. They are, however, usually preserved soft by salting, and dressed for the table.

Para Isinglass.—A substance has lately been imported under the name of isinglass, which, on examination, proves to be, not the air-bag, but the dried ovary of a large fish.

It consists of bunches—somewhat resembling those of grapes—of ovoid or rounded masses, attached by peduncles to a central axis; by immersion in water, the latter is found to be a convoluted membrane, to one side only of which these ovoid masses are attached. When soaked in water, the fishy odor of this so called isinglass is very obvious. The ovoid masses are *ova*, are highly vascular on the surface, and are filled with an animal substance of a yellow color. In general appearance, they resemble the vitellus of a shark or ray.

The *Sudis gigas*, a large osseous fish, upwards of six feet in length, is found at Para. Its flesh is eaten by the lower classes in a dried and salted state, and its swimming bladder constitutes one of the kinds of

Brazilian isinglass imported into London. It is probable that the ovary of this fish constitutes the false isinglass in question. If not from this fish, it is probably obtained from some allied genus—as *Amia*—of highly organized osseous fishes.—*Pereira's Materia Medica*.

PROPERTIES AND COMPOSITION.—The properties of isinglass are nearly the same as those of gelatin.

Isinglass was first analysed by Dr. JOHN, but his results are very questionable. They are as follow:—

	Centesimally.
Gelatin,	70.0
Osmazom,	16.0
Membrane insoluble in boiling water,	2.5
Free acid, and salts of potassa and soda, } with some phosphate of lime,	4.0
Water,	7.5
	100.0

It appears that the Bengal isinglass yields, on analysis, gelatin, albumen, osmazom, a trace of odorous oil, and a small amount of inorganic matter. The quantities of the first two mentioned principles contained in three several samples of isinglass were respectively:—

	Centesimally		
	I.	II.	III.
Gelatin,	86.5	90.9	92.8
Albumen,	13.5	9.1	7.2
	100.0	100.0	100.0

USES.—The more common kinds of isinglass, especially the coarse Brazilian, are used by brewers for fining beer, and have been noticed in their application for that purpose. They are also employed for the clarification of wines, and various other liquids.

Court Plaster is formed by brushing a solution of isinglass, mingled with a little tincture of benzoin, over black sarsenet. LISTON's isinglass plaster is similarly made with oiled silk.

Isinglass also enters into the composition of those preparations known as *marine glue*, *diamond cement*, *et cetera*. The latter is made by dissolving isinglass in dilute alcohol. These ingredients are put in a bottle loosely corked, which is then placed in a vessel containing boiling water, and simmered for about an hour. When cold, it should be an opaque, milk-white, hard jelly; it is re-dissolved by immersion in warm water, the cork of the bottle having been previously loosened. The addition of a little spirit is required, after some time, to replace that lost by evaporation.

A better article than this may be obtained by soaking fine isinglass in cold water; when it has swelled out, spirit is added, and the bottle containing these set in a pan of cold water, which is gradually brought to the boiling point, when the isinglass becomes one uniform pulp, free from lumps or fibres.

These preparations have a tendency to become mouldy, which may be diminished or removed by the addition of a few drops of any essential oil.

ADULTERATION OF ISINGLASS.—The quality of cut isinglass is estimated, says Dr. REDWOOD,—1. By its color; that which is cut fine by machinery being, *ceteris paribus*, the whitest and generally most esteemed. 2. By the odor emitted after breathing upon it; that being the best which is least disagreeable in this respect. 3. By the extent of its solubility in water. 4. By the con-

istency, transparency, and flavor of the jelly which it gives. This practical method of examination is that alone by which slight shades of variance may be discovered; yet a difference of flavor, which only a practised palate, or careful comparison with an approved specimen could detect, is often important in an article intended for the diet of the fastidious invalid, and a slight superiority in this respect will, therefore, command a much increased price.

WARINGTON and REDWOOD have shown that sheet gelatin is rolled between sheets of isinglass in the moistened state, so as to form a ribbon in which the two substances would be united.

This may be detected by means of the microscope, the separate strata being in many cases clearly discernible. The amount of inorganic matter in the product is also a clue as to whether it is or is not adulterated, since isinglass gives an ash of a reddish color, amounting only to a half per cent., while gelatin gives, according to REDWOOD, not less than three per cent. of white ash.

They may also be distinguished from one another, says Dr. REDWOOD, by means of caustic potassa. When cut isinglass is macerated in a cold solution of caustic potassa, it will speedily become transparent, and, after the lapse of a few hours, if occasionally stirred, it will be dissolved, forming a clear and colorless solution. After allowing this to stand for some time, a very slight flocculent precipitate will be deposited, which, in operating on twenty or thirty grains of isinglass, will be scarcely perceptible. Cut gelatin, by the same treatment, becomes opaque; even those specimens which were so, to a certain extent, previously, will assume increased opacity after immersion. The gelatin ultimately dissolves, as does the isinglass; but the solution is not transparent, and after some time a copious flocculent deposit is formed.

A sample of hand-cut isinglass, examined by WARINGTON, had a great deal of acid adhering to it, which he considered to arise either from the acid having been used for the purpose of improving an inferior isinglass, so as to render it saleable, or from its admixture with gelatin prepared by means of an acid.

GLUE.—*Colle forte*, French; *Tischlerlein*, German. —Glue is an impure desiccated gelatin, obtained from various sources. The principal substances employed are scraps of ox and other thick hides, which afford the strongest product; the debris of the tan-yards, of leather-dressers, morocco-leather manufacturers, *et cetera*. The tendons and intestines of many animals, rabbit skins deprived of their fur, scraps of parchment, old gloves, and many other apparently worse than useless matters, all contribute their quota in the manufacture of glue.

When the fresh glue-yielding substances are not to be immediately employed, it is always requisite to submit them to some antiseptic treatment till they are required for use.

This preservation often forms the base of a particular branch of industry, which has for its object to prevent the fermentation of the raw materials, and to dry them to avoid the expenses of transport. These results are obtained by simply macerating them during

fifteen to twenty days in milk of lime, which is repeatedly renewed. After taking them from the lime bath, they are spread in the open air to drain and dry. This desiccation is accelerated by turning them over with a fork several times a day. When sufficiently dried, the materials are packed up and sent to the glue factory.

The calcareous liquor serves to dissolve the blood and some soft parts; it attacks the epidermis, and predisposes the tissue to be more easily converted into gelatin. Before employing these glue-yielding materials, the manufacturer is in the habit of completing these effects by again immersing them in a weak milk of lime, which frees them still further from any soluble animal impurities. When they are much swollen and easily penetrated, they are several times rinsed in water to remove the excess of calcia. They are then spread upon hurdles, being turned occasionally to carbonate the free alkaline earth, which might subsequently be injurious to the glue. It is not necessary, however, to dry the material, as when put into the boiler it dissolves faster when in a soft or tumefied state.

Formerly the glue pieces, having been cleansed as above described, were thrown loose into the caldron, which was of copper, rather shallow in proportion to its area, and flat-bottomed. Above the true bottom there was a false one of copper or iron, perforated with numerous holes, and standing upon feet three or four inches high, the animal matters being thus upheld from contact with the fire.

Now, however, the material is placed in a wide-mouthed bag or net, made of rope, and spread open in the caldron, which contains a light framing of iron, to prevent the bag adhering to the sides or bottom. Water is then added, and gradually brought to ebullition. As the animal substances decrease in bulk, fresh additions are made, the whole being occasionally agitated or pressed down by means of poles.

The progress of the operation is readily ascertained by withdrawing a sample of the menstruum, and setting it aside for a few minutes to cool. If a clear and consistent jelly be obtained, the boiling has been carried to a sufficient extent, and the mouth of the glue-bag having been securely tied up, it is slowly raised by appropriate machinery, until it comes in contact with, or is partially coiled round, a large beam immediately above the caldron, which expels the fluid. In this state it is left to drain. The solution in the boiler will require evaporation before it is sufficiently concentrated for making glue.

The contents of the bag are subjected to ebullition for a second and a third time, and by this means afford size. When the resulting solutions are too dilute for either glue or size, they are employed instead of water for extracting the glue from fresh materials; the refuse in the bags, after all available matter has been extracted, is sold for manure, and every particle of animal substance is turned to account.

When sufficiently concentrated, the glue is transferred from the caldron to the *settling-back*, where such a temperature is maintained, that its fluidity is preserved. The impurities by this means subside, and should the manufacturer wish a very fine product, he

can also at this time add such fining or clarifying agents as he may prefer.

The glue is run off hence into wooden *coolers* or *boxes* about six feet in length, two in depth, and one in breadth. The apartment in which this is done ought to be as cool and dry as possible, to favor the solidification of the gelatinous menstruum, and the floor should be kept scrupulously clean, so that should any glue escape it may be recovered.

Having become a firm jelly, the glue is cut out into cubic masses, each of which is deposited in a kind of wooden box, open to the back in several slits or divisions, of a size corresponding to the thickness which the cakes of glue are required to have. It is then cut into slices by passing a brass wire stretched in a frame, like that of a bow-saw along the slits. The resulting cakes of glue are deposited upon nets, which are stretched in wooden frames, and are thus removed to the sheds, where they are placed in piles, due intervals being allowed for the circulation of the air. They are turned two or three times a day.

The drying of the glue, says Dr. URE, is the most precarious part of the manufacture. The least disturbance of the weather may injure the product during the first two or three days of its exposure. Should the temperature rise considerably, the gelatin may become soft and unshapely, so much so as to run through the meshes upon the pieces below, or to get attached to the strings, and surround them so as not to be separable without plunging the net into boiling water. If frost supervene, numerous cracks may be formed in the cakes, from the congelation of their water. Such pieces must be remelted. Even a slight fog produces, upon newly-exposed glue, a serious deterioration; the damp condensed upon its surface occasioning a general mouldiness. A thunderstorm sometimes destroys the coagulating power in the whole laminæ at once; or causes the glue to *turn* on the nets. A wind too dry or too hot may cause it to exsiccate so quickly, as to prevent it from contracting to its proper size without numerous cracks and fissures. Thus, as TOMLINSON remarks, the manufacture is subject to many vicissitudes, and can only be profitably and conveniently carried on in temperate and equable weather. The drying, however, is not entirely finished in the open air. When the glue is about three parts dry, it is removed into lofts, where, in the course of some time, the hardening is completed. But, as the surfaces of the cakes become mouldy and soiled, it is necessary to scour them with a brush and hot water, and set them up to drain. They are then finally desiccated in a stove-room at an elevated temperature, which, when they have once become solid, only serves to harden and improve them.

In France, a considerable quantity of glue is made from bones, which are digested in hydrochloric acid, for the purpose of removing the phosphate of lime.

The following is the *modus operandi*:—It is proper to observe that all bones do not answer for this manufacture. Only spongy bones can be used; the ribs, the back-bone, the lower jaw-bone of animals, and the horns, are those which yield the greatest amount of gelatin. The bones are broken as small as possible by means of an axe. Some hydrochloric acid of

36° Twaddell is mixed with a quantity of water, so as to reduce the mixture to 13°, which can be ascertained by means of the acidimeter. The crushed bones are put into a vessel, and the above-mentioned preparation poured over them so as to cover them completely. The vessel is covered close with a wooden lid, and the bones are thus left to macerate for thirty hours. When this period has elapsed, it must be seen if the bones are softened; for otherwise, if the acid was deficient in strength to extract from them the lime and alkali, in that case it would be requisite to change the vessel, and to give them a new maceration with a mixture of 9° Twaddell strength. When sufficiently prepared they are withdrawn, and thrown into a bath of weak lime-water, where they are left to steep eight days; they are then removed, washed with fresh water, and put to steep in a fresh portion of water daily for ten or twelve days, for the purpose of removing from the bones the acid which may have penetrated them—then dried. These glues or pastes are now good for the market, and sell at about fifty shillings the six hundred pounds.

This, says Dr. URE, is a poor article, possessing little cohesive force. It dissolves almost entirely in cold water, which is the best criterion of its imperfection.

PROPERTIES.—Glue is commercially judged of by its color, and freedom from cloudy or black spots when held up before the light.

The better sorts of glue are transparent, especially the thin cakes of *Salisbury glue*, which are of a clear amber color. The chemical characteristics of glue are similar, as a matter of course, to those of pure gelatin.

According to SCHATTENMANN, fresh glue dries much more readily than glue that has been once or twice melted. He states that dry glue absorbs different quantities of water in proportion to its quality, and on this property he has proposed a method of testing it.

Fresh glue contains water of composition, or water more intimately united with the glue than that which it acquires during the melting. The combined water of dry glue disappears in the course of successive meltings and solidifications.

Glue in thin laminæ is usually of better quality than that which is in thick ones, even when made from the same material, because the former admit of a more rapid desiccation than the latter.

In applying SCHATTENMANN's test, dry glue is immersed for twenty-four hours in water at a temperature of about 60°. A jelly is thus formed, the qualities of which will fairly represent those of the glue. For example, the finest ordinary glue, or that made from white bones, absorbs, in the time specified, twelve times its weight of water, so that a plate weighing three grammes produces thirty-nine of fine elastic jelly. Glue from dark bones takes up nine times its weight of water, and a soft brown jelly is produced, devoid of elasticity and consistency, and falling to pieces when handled.

Well-dried glues are much less hydrometric than badly made ones, or those fabricated from inferior materials. The latter are liable to putrefaction.—Tomlinson.

APPLICATIONS.—The common, but important use of

glue in carpentry, cabinet-making, *et cetera*, is well known.

There was formerly a large consumption of it for the sizing of paper; but since this has been made without manual labor, it is almost wholly disused for this purpose.

The hatter employs it in the preparation of his felt; and the letterpress printer, in conjunction with molasses, as a flexible and cleanly covering for his inking rollers.

At the beginning of this century, glue was introduced in Germany for making moulds for casting, but it was not employed in this country till the year 1826, when DOUGLAS FOX used it for taking casts of anatomical preparations, calcareous concretions, vegetal substances, *et cetera*. He first mixed it with treacle, for the purpose of giving to it more elasticity, but this discolored all white surfaces, and the plan was abandoned.

In 1844, FRANCHI formed a series of casts in plaster composition, in imitation of ivory; and, in 1846, the Society of Arts in London awarded to him a prize. The nature of the material was unknown at the time, but it was subsequently shown to be pure gelatin. The inventor has since employed it for modelling very intricate and ingenious devices.

STATISTICS.—A very large amount of glue, manufactured in England, is undoubtedly passed off as Russian; yet, nevertheless, a considerable quantity is imported. The returns of imports and exports, from the years 1850 to 1855, are subjoined. The reader cannot fail to notice the large decrease in the quantity imported during 1855, owing to the hostilities with Russia:—

	1850.	1851.	1852.	1853.	1854.	1855.
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
Imports,.....	1305	1323	1625	3359	4905	781
Exports,.....	—	1	—	46	19	—

The quantity of isinglass imported, principally from the dominions of the Tzar, during the years 1850-5, was as under:—

IMPORTS.					
1850.	1851.	1852.	1853.	1854.	1855.
Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
2009	2387	2056	1730	1881	1567

And the exports during the same period were:—

1850.	1851.	1852.	1853.	1854.	1855.
Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
78	145	117	252	72	205

The imports and exports of gelatin for the years 1850 to 1855 inclusive, were as under:—

	1850.	1851.	1852.	1853.	1854.	1855.
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
Imports,.....	449	295	271	275	269	268
Exports,.....	—	1	2	1	—	3

The quantity imported is gradually lessening, owing, most probably, to the great improvements which have been effected in the British manufacture during the last few years.

GLASS.—*Verre*, French; *Glas*, German; *Vitrum*, Latin.—The discovery of glass is, without contradiction, one of the most important services which accident or chemistry has rendered to civilization. Without speaking of the economical uses of this compound, and considering it only with reference to its applications in the

study of natural phenomena, it is impossible to doubt the singular influence it has exerted on the progress of science. It is chiefly by its aid that astronomy has attained a perfection so wonderful; by it also naturalists have been enabled to study under the microscope a host of phenomena which heretofore escaped notice. But perhaps of still greater importance is the use which is made of it by chemists in their experiments. It requires no profound chemical knowledge to recognize the fact, that to glass is chiefly owing the present advanced state of the sciences, so fruitful in marvellous applications. Every one, says LIEBIG, is familiar with most of the properties of this curious substance; its transparency, hardness, destitution of color, and stability under ordinary circumstances: to these obvious qualities one may add those which especially adapt it to the service of the chemist, namely, that it is unaffected by most acids or other fluids. At certain temperatures it becomes more ductile and plastic than ware, and may be made to assume in the flame of a common lamp the form of every vessel needed in the laboratory, and of every apparatus required by experimenters.

The use of glass in our windows, remarks TOMLINSON, instead of the louvre boards of old, has introduced a degree of comfort into the meanest dwelling which previously did not appertain to the costliest palace. By means of this contrivance the light is filtered from the wind, the rain, and the cold; the one can be enjoyed without being inconvenienced by the other; and one can, in conjunction with the improved methods of warming, create an in-door climate, adapted to the desires and feelings of the dwellers. The employment of glass in many domestic articles of furniture contributes to cleanliness and health, for the slightest soil on glasses or decanters is revealed by this most transparent material, and the purity of the water and other liquids contained in them is physically tested by the same means. Even the mirror, adorning the rooms, reminds one of the necessary attention to personal appearance, which self-respect, as well as respect for society, demands.—Tomlinson.

The great Dr. JOHNSON has appositely remarked, that it might contribute to dispose one to a kinder regard for the labors of his fellow, if he were to consider from what unpromising beginnings the most useful productions of art have probably arisen. Who, when he first saw the sand or ashes, by casual intense-ness of heat, melted into a metalline form, rugged with excrescences and clouded with impurities, would have imagined that in this shapeless lump lay concealed so many conveniences of life, as would, in time, constitute a great part of the happiness of the world? Yet, by some such fortuitous liquefaction was mankind taught to procure a body, at once in a high degree solid and transparent, which might admit the light of the sun, and exclude the violence of the wind; which might extend the sight of the philosopher to new ranges of existence, and charm him, at one time, with the unbounded extent of material creation, and at another with the endless subordination of animal life; and what is of yet more importance, might supply the decays of nature, and succour old age with subsidiary sight. Thus was the first artificer in glass employed, though

without his knowledge or expectation. He was facilitating and prolonging the enjoyment of light, enlarging the avenues of science, and conferring the highest and most lasting pleasures: he was enabling the student to contemplate nature, and the beauty to behold herself.

It is not a little remarkable that glass, which is applied so extensively and to so many purposes, and the varying properties of which exercise so marked an influence in its different applications, has, notwithstanding, never been the subject of a series of decisive experiments, calculated to establish the theory of its fabrication. Not that this theory has not been nearly, if not wholly elucidated; but that it is scarcely to be looked for in the works published on glass. The greater part of these were written at a period when the part which silicic acid performed was not defined or understood; and among the recent works on the subject, KNAPP'S is the only one which discusses it in a thoroughly scientific manner.

Definition.—It is stated in the Encyclopedia Britannica, that the general term *glass* is employed by chemists to denote all mineral substances which, on the application of heat, pass through a molten state into hard and brittle masses, and which exhibit when broken, though not always transparent, a lustrous fracture. The glass of commerce, however, to which the present article will be restricted, or the transparent and artificial substance which is usually distinguished by this name, is produced by the igneous fusion of silicious earth with certain alkaline earths or salts, or with metallic oxides.

The etymology of the word has been much disputed. It is derived by some from the Latin *glacies*, ice, its resemblance to which is thought to have suggested the title, and *glacies* may be a contraction for *gelacies* from *gelu*, frost. Others have remarked, that the common Latin designation of this substance is *vitrum*; and as the Romans applied this term, in common with the word *glastum*, to the plant which is now called woad, they have deduced it from the latter of these, either because the ashes of this plant were used in the manufacture of glass, or because it exhibited something of the bluish tinge which is procured from woad. *Glassum*, the name given to amber by the ancient Gauls and Britons, has also been assigned as the origin of the word. But none of these etymons appears very satisfactory. The most plausible theory is that which derives the term from the Saxon verb *glis-nian*, or the German *gleissen*, which are probably contractions of the Anglo-Saxon *gel-iscan*, to shine, to be bright. This view is in a great degree confirmed by the sense in which the term glass and its derivatives are employed by our older writers, who frequently apply it to shining or glittering substances, without reference to color or transparency.—*Encyclopedia Britannica*.

HISTORICAL NOTICE.—In the most remote ages the art of blowing glass into bottles, making it into vases, tinging it to imitate precious stones, melting it in huge masses to make pillars, rolling and polishing it into mirrors, and staining it in parts, were all perfectly known. As stated by some authorities, Egypt, the parent of so many collateral arts, is to be looked to as its source. According to others, its discovery origi-

nated with the Israelites, who set fire to a forest, and the heat becoming so intense as to make the nitrate of soda and sand melt and flow along the mountain side, they afterwards imitated artificially what had first been effected by accident. If PLINY is to be credited—an author, whose version of the subject has so often been reproduced with all the gravity of history—the discovery of glass was made by some Phœnician soda merchants, who, having landed on the banks of the river Belus, served themselves with blocks of soda to support the vessel in which they prepared their food, and these masses melting with the heat, transformed into glass the sand on which they rested. When one knows the temperature necessary for the making of glass, and has seen the interior of a glass furnace in operation, this story will be rejected as fabulous. Chance had doubtless its share in the invention of glass; but there might have been found among the arts known to the ancients, phenomena better fitted to awaken the attention of an observant spirit. The pottery manufacture and the extraction of metals require the employment of violent and sustained fire, which is sufficient to give rise to fusible silicates, more or less analogous to glass. That an intelligent potter might have attempted to reproduce at pleasure the vitreous tears which formed accidentally upon his products; that by dint of repeated trials he might have been led to remark the influence of ashes on the clay, and that thus he might have succeeded in producing glass, is easily conceived. However this may be, the anecdote related by PLINY ought to be ranked with those idle tales or mere conjectures by which the ancient commentators sometimes attempted to fill the gap created by the silence of history, and which were afterwards transformed into articles of faith by some mistake of a copyist, or by some blunder of a new commentator. It is a point, however, on which there can be no doubt, that glass was known to the Phœnicians, who for a long time retained the monopoly of it, favored by the union of natron, sand, and fuel, in a country situated on the shores of the sea.

There are several references to glass in the Bible. BALLANTYNE remarks that the Hebrews must have become acquainted with glass while in Egypt, and in consequence of their proximity to the Phœnicians; and it is now generally believed that these two nations had the merit of originating and establishing its manufacture. It is a remarkable circumstance that glass lenses have been found during the recent researches in the ruins of Nineveh. The Athenian ambassadors, in order to give an idea of the magnificence displayed at the court of the great king of Persia, said that they drank in cups of glass and gold. Some writers affirm that the Egyptians, in some instances, sealed up their dead in a coating of glass; and glass houses are said to have been not uncommon in that wonderful country. Some authors ascribe, with very plausible reason, the discovery of glass-making to the priests of Vulcan at Thebes and Memphis, the greatest chemists in the ancient world. The Egyptians are also known to have made enamels of divers hues which they applied on pottery, magnificent specimens of which are still extant, and are called Egyptian porcelain. These are chiefly covered with a

beautiful blue or green tinge, and groups of flowers or other designs are traced in black. Glass beads and other ornaments made of that substance, skilfully manufactured and beautifully tinged, have been found adorning mummies, which are known to be upwards of three thousand years old. It is certain that Tyre, Sidon, and Alexandria were long celebrated for their glass, and furnished the greater proportion of that used at Rome. Under the Roman empire the Egyptians still preserved their superiority in the art of glass-making, and it is said that AURELIAN caused them to pay their tribute in that manufacture. ADRIAN mentions that he had received drinking-glasses of various shades from a priest of a famous temple in Egypt, and gives instructions that they are not to be used but on the greatest occasions, and on the most solemn feast days. To these places the art was exclusively confined for some centuries, and glass was used as an article of luxury, being chiefly in the form of urns or drinking cups of the most elaborate workmanship, and exquisitely embellished with raised, chased, or ornamented figures. The Barberini or Portland vase, composed of a deep azure glass, with figures of a delicate white opaque substance raised in relief, is a splendid specimen, and was found in the tomb of ALEXANDER SEVERUS.

Sir J. G. WILKINSON adduces three distinct proofs that the art of glass-working was known in Egypt before the exodus of the children of Israel from that land, three thousand five hundred years ago. At Beni Hassan and at Thebes are paintings representing, in a very rude form, glass-blowers at work; and from the hieroglyphics accompanying them, it is found that they were executed in the reign of a monarch who occupied the throne at about that period. It is certain, moreover, that at that time images of glazed pottery were common, the vitrified material of which is of the same quality as glass; and, therefore, the mode of fusing, and the proper proportions of the ingredients for making glass, must have been already well known. Lastly, Sir J. G. WILKINSON adduces the instance of a glass bead about three-quarters of an inch in diameter, which Captain HENRY found at Thebes, and which contains in hieroglyphic characters the name of a monarch who lived fifteen hundred years before CHRIST. The knowledge of the manufacture probably travelled from Egypt to Greece, thence to Rome and modern Europe; and successive improvements have not only brought the art to a high degree of excellence, but have led to its subdivision into several kinds, such as flint-glass, plate-glass, window-glass, and green or bottle-glass making. —*Dodd.*

The art of glass-making seems to have been introduced into Italy by the Romans after their conquests in Asia, in the time of CICERO, and the first glass-works there were said to have been near the Flaminian Circus. It is highly probable that the workmen were imported from Egypt. The use of glass seems to have rapidly extended, and to have become very common. One of the emperors in the third century of the Christian era says, that he was disgusted with an article so mean and vulgar as glass, and that he would only drink from vessels of gold. By this time the manufacture of glass was so considerable that an impost was laid on

it, and it was extensively employed in the decorations of buildings. In glass mosaics particularly were combined the most brilliant colors.

From the circumstance of colored glass beads and amulets having been found among Druidical remains in this country, says BALLANTYNE, it has been argued by PENNANT and others, that the art of making glass was known in Britain before its invasion by the Romans. It can hardly be believed, however, that a people who had made very trifling advances in civilization, and who, it is known, were entirely unacquainted with any other art, should be found not only conversant with the use of glass, a complicated and highly ingenious process, but should excel in it; for the beads and amulets spoken of are of exquisite workmanship, and beautifully colored in imitation of the rarest and most precious stones. There seems little doubt, therefore, that the ancient Britons procured these in their traffic with the Syrians, who visited this island, as the modern Britons and other civilized nations visit the South Sea islands, to drive a trade with their savage inhabitants in toys and trinkets, giving these in exchange for skins or other natural productions. By whatever means, however, these ornaments came into Britain, it is certain that they were in extensive use, though principally for superstitious purposes, long prior to the Roman invasion, as they are found in barrows or tumuli of a much older date. One at Stonehenge, in particular, on being opened, was found to be filled with them.

Glain Neidyr, or druidical glass rings, generally about half as wide as our finger rings, but much thicker, have frequently been found. The vulgar superstition regarding these was, that they were produced by snakes joining their heads together and hissing, when a kind of bubble like a ring was formed round the head of one of them, which the others, continuing to hiss, blew upon till it came off at the tail, when it immediately hardened into a glass ring. Success was thought to attend any one who was fortunate enough to find one of those snake stones. They were evidently beads of glass employed by the Druids, under the name of charms, to deceive the vulgar. They are usually of a green hue, but some of them are blue, and others variegated with wavy streaks of blue, red, and white.

Glass utensils have been found in Herculaneum, which city was destroyed by an eruption of Mount Vesuvius in the reign of TITUS. A plate of glass also found there has occasioned much speculation as to its uses. Similar plates, to which PLINY gives the name of *vitrea camera*, seem to have been employed in a manner not now very well understood, as panelling for their rooms. It is certain that two panes of glass were found in a window in Herculaneum.

In the reign of TIBERIUS, a company of glass manufacturers established themselves in Rome, and they had a street assigned them near the Porta Capena. The articles of their manufacture were few in number, and of inferior quality; neither did they make rapid improvements in their art, notwithstanding the large prices which were then given for glass of foreign manufacture in the imperial city. In the year 220, they had increased so much in importance, and the product was so considerable, that an impost was laid on it by

ALEXANDER SEVERUS. DION CASSIUS and PETRONIUS ARBITER concur in their account of the discovery of malleable or ductile glass by a celebrated Roman architect, whose success in the restoration to its position of a portico which leaned to one side, had roused the envy and jealousy of TIBERIUS, and occasioned his banishment from Rome. Thinking that his discovery would disarm the Emperor's wrath, the artist appeared before him bearing a glass vessel, which he dashed upon the ground. Notwithstanding the violence of the blow, it was merely dimpled, as if it had been brass. Taking a hammer from his breast, he then beat it out into its original shape; but instead of giving him the reward which he had expected, the Emperor ordered the unfortunate artisan to be beheaded; remarking, that if his discovery were known, gold would soon be held of as little value as common clay. This is probably another version of the story told by PLINY, of an artificer who made the same discovery, and whose workshop was demolished by those who had an interest in preventing the introduction of an article which would lower the value of gold, silver, and brass. Although it might not be justifiable to give unqualified discredit to these tales, yet the knowledge at present possessed would restrict the possibility of such a discovery within the narrowest limits. The union of the properties of malleability and vitrification seems to be incompatible. Some metallic substances, by the application of intense heat, are reduced to the state of glass, but at the same time lose their malleability; which fact would seem to imply that it is impossible to communicate the latter property to glass. The extraordinary stories above-mentioned have, however, been rationally enough explained by modern chemists. It has been observed by KUNCKEL, that a composition having a glassy appearance, and sufficiently pliant to be wrought by the hammer, may be formed; and by NEUMANN, that, in the fusion of chloride of silver, a kind of glass results, which may be shaped or beaten into different figures, and may be pronounced in some degree ductile. BLANCOURT mentions an artist who presented a bust of ductile glass to the Cardinal RICHELIEU; but he does not seem to have been more fortunate than his predecessors; for he was doomed to imprisonment for life, for the *politic reason*, as BLANCOURT with much simplicity observes, which led the Cardinal to fear lest the established interests of French glass manufacturers might be injured by the discovery. From expressions used by BLANCOURT in other parts of his work, it is thought that by malleable glass, such as was produced by this artist, he understood some composition similar to those which KUNCKEL and NEUMANN discovered, and was not very exact in limiting the term to that vitreous substance which is now generally understood when glass is mentioned.

The precise period at which the making of window-glass was introduced, is not now certainly known. Roman windows were filled with a semi-transparent substance called *lapis specularis*, a fossil of the class of tales, which readily splits into thin smooth laminae, or plates. This substance is found in masses of ten or twelve inches in breadth, and three in thickness; and,

when sliced, very much resembles horn, instead of which it is to this day often employed by lantern-makers. The Romans were chiefly supplied with this article from the island of Cyprus, where it abounds. So good a substitute for glass is it said to have been, that, besides being employed for the admission of light, it was also used in the construction of hothouses, for raising and protecting delicate plants; so that, by using it, the Emperor TIBERIUS had cucumbers at his table throughout the whole year.

There is no positive mention of the use of glass for windows before the time of LACTANTIUS, at the close of the third century. But the passage in that writer which records the fact, also shows that the *lapis specularis* still retained its place. Glass windows are distinctly mentioned by St. JEROME, as being in use in his time. A century later, the windows of the church of St. SOPHIA at Constantinople are represented, by PAULUS SILENTIARIUS, as being filled with glass. After this period, frequent mention is made of them. JOANNES PHILIPPINUS states that glass was fastened into the windows with plaster.

BIDE asserts that glass windows were first introduced into England in the year 674, by the Abbot BENEDICT, who brought over artificers skilled in the art of making window-glass, to glaze the church and monastery of Wearmouth. Other authorities attribute the introduction of this luxury to Bishop WILFRED, junior, who died in 711. It would thus appear, that glass windows were first seen in England either about the seventh or the beginning of the eighth century. The use of window-glass, however, was then, and for many centuries afterwards, confined entirely to buildings appropriated to religious purposes; but, in the fourteenth century, it was so much in demand, though still confined to sacred edifices and ornamental purposes, that glazing had become a regular trade. This appears from a contract entered into by the authorities of York Cathedral in 1338, with a glazier, to glaze the west windows of that structure; a piece of work which he undertook to perform at the rate of sixpence per foot for white glass, and one shilling per foot for colored. Glass windows, however, did not become common in England till the close of the twelfth century. Until this period they were rarely to be found in private houses, and were deemed a great luxury, and a token of great magnificence. The windows of the houses were, till then, filled with oiled paper or wooden lattices. In cathedrals, these, and sheets of linen, supplied the place of glass till the eighth century; in meaner edifices, lattices continued in use till the eighteenth.

The glass of the Venetians was superior to any made elsewhere, and for many years commanded the market of nearly all Europe. Their most extensive glass-works were established at Murano, a small village in the vicinity of Venice; but the produce was always recognized as Venetian glass. Baron von LOWEN states that, so useful were the glass-makers at one period in Venice, and so great the revenue accruing to the republic from their manufacture, that, to encourage the men engaged in it to remain in Murano, the senate made them all burgesses of Venice,

and allowed the nobility to marry their daughters; whereas, if a nobleman married the daughter of any other tradesman, the issue were not reputed noble.

The skill of the Venetians in glass-making was especially remarkable in the excellence of their mirrors. BECKMANN, who has minutely investigated the subject, is of opinion that the manufacture of glass mirrors certainly was attempted, but not with complete success, in Sidon, at a very early period; but that they fell into disuse, and were almost forgotten until the thirteenth century. Previously to this period, plates of polished metal were used at the toilette; and in the rudeness of the first ideas which suggested the substitution of glass, the plates were made of a deep black color to imitate them. Black foil even was laid behind them to increase their opacity. The metal mirrors, however, remained in use long after the introduction of their fragile rivals; but at length they wholly disappeared—a result effected chiefly by the skill of the Venetians, who improved their manufacture to such a degree, that they speedily acquired a celebrity which secured an immense sale for them throughout all Europe.

From Italy the art of glass-making found its way into France, where an attempt was made to rival the Venetians in the manufacture of mirrors. The first essay was unsuccessful; but another, made under the patronage of the celebrated COLBERT, in which French workmen who had acquired a knowledge of the art at Murano were employed, had better fortune. But a few years afterwards, this establishment, which was situated in the village of Toulaville, near Cherbourg, in Lower Normandy, was also threatened with ruin by a discovery or rather improvement in the art of glass-making, effected by one ABRAHAM THEVART. This improvement consisted in casting plates of much larger dimensions than it had hitherto been deemed possible to do. THEVART's first plates were cast at Paris, and astonished every artist by their magnitude. They were eighty-four inches long and fifty inches wide, whereas none previously made exceeded forty-five or fifty inches in length.

In 1695 the two companies, THEVART's and that at Toulaville, united their interest, but were so unsuccessful, that in 1701 they were unable to pay their debts, and were, in consequence, compelled to discharge most of the workmen, and abandon several of their furnaces. Next year, however, a company was formed, under the management of ANTOINE D'AGINCOURT, who re-engaged the discharged workmen; and the works realized considerable profits to the proprietors—a circumstance which is attributed wholly to the prudent management of D'AGINCOURT.

Early in the fourteenth century, the French government made a concession in favor of glass-making, by decreeing, that not only should no derogation from nobility follow the practice of the art, but that none, save gentlemen or the sons of noblemen, should venture to engage in any of its branches, even as working artisans. This limitation was accompanied by a grant of a royal charter of incorporation, conveying important privileges, under which the occupation became eventually a source of great wealth to several families of distinction.

It has been said that the manufacturing of window-glass was first introduced into England in the year 1557. But a contract quoted by HORACE WALPOLE proves that this article was made in England upwards of a century before that period. This curious document is dated 1439, and bears to be a contract between the Countess of WARWICK and JOHN PRUDDE of Westminster, glazier, whom she employed, with other tradesmen, to erect and embellish a magnificent tomb for the Earl, her husband. JOHN PRUDDE is thereby bound to use no glass of England, but glass from beyond seas; a stipulation which, besides showing that the art of making window-glass was known and practised in England in the fifteenth century, seems also to indicate that the article made was inferior to what could be obtained from abroad. The finest sort of window-glass was first made at Clutched Friars, London, in 1557. The first flint-glass made in England was manufactured at the Savoy House, in the Strand; and the first plate-glass, for looking-glasses, coach windows, and similar purposes, was manufactured at Lambeth by Venetian workmen, brought over in 1670 by the Duke of BUCKINGHAM. From that period the English glass manufactories, aided by the liberal bounties granted them in cash upon glass sold for export, became powerful and successful rivals of the Venetian and French manufactories. The bounty on glass exported, which the government paid to the manufacturer, was not derived from any tax by impost or excise previously laid; for all such were returned to the manufacturer, together with the bounty, thereby lessening the actual cost of the article from twenty-five to fifty per cent., and enabling the English exporter to compete successfully in foreign markets. This bounty provision was annulled during the premiership of Sir ROBERT PEEL, together with all the excise duty on home consumption.

The art of glass-making was introduced into Scotland in the reign of JAMES VI. An exclusive right to manufacture it within the kingdom, for the space of thirty-one years, was granted to Lord GEORGE HAY in the year 1618. This right his lordship transferred in 1627, for a considerable sum, to THOMAS ROBINSON, merchant-tailor in London, who again disposed of it for two hundred and fifty pounds to Sir ROBERT MANSELL, vice-admiral of England. The first manufactory of glass in Scotland, an extremely rude one, was established at Wemyss, in Fife. Regular works were afterwards commenced at Prestoupans, Leith, and Dumbarton.

Crown-glass is now manufactured at Warrington, St. Helen's, Eccleston, Old Swan, and Newton, Lancashire; at Birmingham, Hunslet, near Leeds, and Bristol. It is also fabricated of excellent quality on the Tyne and Wear. Great improvements have recently been made in the manufacture of crown-glass, and it is asserted that this article, as made in England, is superior in quality to that of any other nation.

According to BALLANFYNE, the manufacture of glass was introduced into the American States in 1790, by ROBERT HEWES, a citizen of Boston, who erected a factory in the then forest of New Hampshire. The chief aim of Mr. HEWES was to supply window-glass, but he did not succeed. Another attempt was made in 1800, when a factory was built at Boston for making

crown window-glass; but this was also unsuccessful, till a German named LINT, in 1803, took charge of the works, and the state of Massachusetts agreed to pay the proprietors a bounty on every table of window-glass they made, after which the manufacture was carried on successfully, the glass steadily improving in quality, and becoming famed through all the States as Boston window-glass. The same company erected new and more extensive works at Boston. The mystery attached to the art of glass-making followed it into America. The glass-blower was considered a magician, and myriads visited the newly-erected works, looking on the man who could transmute earthy and opaque matter into a transparent and brilliant substance, as an alchemist who could change base metal into gold.

Since the manufacture of flint-glass originated in the Eastern States, there have been above forty companies formed from time to time, nearly thirty of which have proved failures. There are now ten in operation, two of which are at East Cambridge, three at South Boston, one at Sandwich, three near New York city, and one at Philadelphia. Forty-eight thousand tons of coal, six thousand five hundred tons of silica, two thousand five hundred tons ash, nitrate of soda, *et cetera*, and three thousand eight hundred tons of lead, are annually consumed in the manufacture of flint-glass.

In the vicinity of Pittsburgh, in the Western States, are nine manufactories of flint-glass, and ten of window-glass, and in the river towns are fifteen window-glass factories.

There is good reason for supposing that the art of staining or painting glass is coeval with the art of making glass itself, since, as will be afterwards seen, it is difficult to make it without color. The possibility of subjecting this propensity to the will of the manufacturer must have very obviously presented itself, although it certainly requires much art and chemical knowledge to produce perfect specimens of this description of manufacture. This perfection seems, however, to have been attained at a very early period. It is certain that the art was known in Egypt three thousand years ago. The beautiful imitations of precious stones found adorning mummies which are known to have existed for that time have been already noticed; and frequent mention of specimens of Eastern workmanship of consummate beauty are met with, upon which great value was placed. Allusion has also been made to the fact, that the Emperor ADRIAN, whilst at Alexandria, was presented, by an Egyptian priest, with two glass cups, which sparkled with hues of every kind, and which had been used in the service of the temple—a present so highly prized by the Emperor, that he ordered them to be produced only on festivals and great solemnities. The works of CAYLUS and WINKELMANN furnish some striking instances of ancient skill in the formation of pictures by means of delicate glass fibres of various hues, which, after being fitted together with the utmost nicety, were conglutinated by fusion into a solid mass. The art of combining the various tints, so as to produce pictures in the manner now practised, is comparatively of recent date. The earliest specimens of this kind of work discover a factitious joining of different pieces of glass, differently tinged, and so ar-

ranged as, by a species of mosaic work, to produce the figure or figures wanted. The various pieces are held together generally by a vein of lead, run upon the back of the picture, precisely at their junction.

But modern ingenuity has superseded this clumsy expedient; and every color used in painting can now be introduced into one entire sheet. For a long period the pictured glass used in cathedrals was merely painted on the surface, the art of incorporating the tints with the glass by fusion, the method now practised, being unknown till the beginning of the fifteenth century. This great improvement is ascribed to a painter of Marseilles, who went to Rome during the pontificate of JULIUS II.; but his discovery went no further than the producing of different colors on different pieces of glass, and having them afterwards united in the old fashion. This art was, at a later period, greatly improved by ALBERT DURER and LUCAS of Leyden, the latter of whom brought it nearly to the state of perfection in which it now exists.

The first painted glass executed in England was in the time of King JOHN; previous to this, all stained or painted glass was imported from Italy. The next notice of it occurs in the reign of HENRY III. The treasurer of that monarch orders that there be painted, on three glass windows in the chapel of St. JOHN, a little Virgin Mary holding the Child, and the Trinity, and Saint John the Apostle. Some time after he issues another mandate for two painted windows in the hall.

Even at this early period, however, England boasted of eminent native artists in glass painting, amongst the first of whom was JOHN THORNTON, glazier of Coventry. This person was employed, in the time of HENRY IV., by the dean and chapter of York cathedral, to paint the eastern window of that splendid edifice; and for the beautiful and masterly workmanship which he exhibited in this specimen of skill, he received four shillings per week of regular wages. He was bound to finish the work in less than three years, and to receive, over and above the weekly allowance, one hundred shillings for each year; and, if the work was finished to the satisfaction of his employers, he was to receive, on its completion, a further sum of ten pounds. It must be recollected that the value of money was at that time much higher than in modern days.

From this period downwards there have been many skilful native artists, although the Reformation greatly impeded the progress of the art, by banishing what was deemed the ungodly ostentation of ornamented windows from churches; indeed, so serious was this interruption, that the art had nearly altogether disappeared in the reign of ELIZABETH. Amongst the most eminent glass painters who first appeared upon the revival of the art, were ISAAC OLIVER, born in 1616, and WILLIAM PRICE, who lived about the close of the seventeenth century. This last person was for many years the only glass painter in England. He is said to have discovered, what is to this day a desideratum in the art of glass staining, the secret of producing a rich, clear, bright, and transparent red, the most difficult to strike, and the most expensive of all the hues employed in glass painting. But PRICE having died soon after making this discovery, his secret was never divulged. This

artist was succeeded by a person at Birmingham, who, in 1757, fitted up a window for Lord LYTTLETON, in the church of Hajely. To him succeeded one PECKIT of York, who attained considerable eminence in the art.

During all this time, however, and indeed until a comparatively recent date, painted glass was regarded as too costly and too magnificent an article to be otherwise employed than in decorating religious edifices, or the palaces of nobles; and even in the latter case was but sparingly used. Modern improvement has now placed this beautiful ornament within the reach of very ordinary circumstances; and when this is considered, it must excite a strong feeling of surprise to find how little so elegant a luxury is even yet in demand. The art of staining glass is now practised with very great success. The colors of modern artists, notwithstanding what is often urged to the contrary, equal in variety and richness those of the ancients; and, with the superior knowledge which is now possessed of the principles of drawing, and of bringing several colors together on a single sheet, encouragement alone is wanting to attract artists of talent and inventive genius to the pursuit of the art, and to carry it to a greater degree of excellence than it has ever reached in the hands of their predecessors.—*Encyclopedia Britannica*.

NATURE AND COMPOSITION OF GLASS.—The researches of BERZELIUS having removed all doubts concerning the acid character of silica, the general composition of glass now presents no difficulty of conception. This substance is the product of fusion at a high temperature of silica, or silicic acid, sometimes of boracic acid, with different salifiable bases, as potassa, soda, lime, magnesia, baryta, oxide of lead, oxide of tin, protoxide of iron, protoxide of manganese, alumina, and the sesquioxide of iron, and binoxide of manganese; the product solidifies after fusion in the form of a transparent mass, which is either colorless or not, according to the ingredients which it contains; it combines a great degree of hardness with the property of resisting the destructive action of air, water to a certain extent, and even that of the more powerful chemical agents.

It is well known that silica acts the part of a powerful acid at the temperature of a red heat, and is capable of expelling carbonic acid, hydrochloric acid, *et cetera*, from compounds, and combining with the bases named above, giving rise to solid combinations. Glass, in short, is a true salt—a silicate, and is an artificial production of a similar character to those compounds which occur so abundantly in nature; it differs, however, from these in one essential particular, that it possesses a distinctly non-crystalline structure; or is, as it is scientifically termed, *amorphous*. Glass, as is well observed by KNAPP, may be said to bear the same relation to a natural silicate of like composition, that melted sugar does to the ordinary crystallized substance.

Special Effect of the Different Constituents.—Although, in a purely chemical view, the potassa, soda, lime, oxide of lead, alumina, and oxide of iron, perform the same part, it is, nevertheless, very evident that, in practice, the employment of one of these bodies cannot be substituted indifferently for that of one or other of its analogues. There necessarily results in the product differences of fusibility, of ductility, of hardness, *et cetera*,

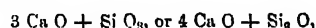
which must be taken into consideration. Hence the necessity of classing glasses according to their composition and properties. This classification will be given afterwards. In the meantime, the characteristic effect of the different constituents on the nature of the glass may be briefly stated:—

The *silicates of soda and potassa* are the most fusible, and so much the more in proportion to the greater amount of the alkaline bases. One part of silica with two to three of potassa or soda, produces a glass which is fusible at a cherry-red heat, and soluble in cold water. Equal parts of alkali and silicic acid—silica—form a glass readily fusible, but imperfectly soluble. One equivalent of soda or potassa combined with six equivalents of silicic acid, and therefore represented by the formula,



yield a compound fusible only by the heat of a very powerful forge. Potassa is more efficacious than soda in rendering the glass easy of fusion. A more brilliant lustre results from the use of soda, but at the same time a bluish-green tint is communicated to the glass. No coloring action is exerted by potassa; but the brilliancy of the glass is somewhat diminished by it.

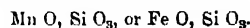
The *silicates of lime* are much less fusible than those of the alkalis. The most fusible of the former, represented by the formula $\text{Ca O} + \text{Si O}_2$, requires for its fusion the violent heat of a forge. The others, represented by



are only softened at the same temperature; the corresponding *silicates of magnesia* are not more fusible. Lime increases the hardness of the glass, and adds more to its lustre than the alkalis, without coloring the produce.

The *silicates of alumina* are still more refractory than the preceding. The least infusible, represented by $\text{Al}_2 \text{ O}_3, 3 \text{ Si O}_2$, is scarcely softened in the heat of a furnace. Of all the ingredients, alumina exerts the most powerful effect in increasing the difficulty of fusion.

The *silicates of the protoxides of iron and manganese* are more fusible than those of lime and magnesia, especially when they consist of one equivalent of each ingredient, thus—



The silicate of protoxide of iron has a dark-green color, but may be decolorized by bringing it to the state of a silicate of the sesquioxide; this is effected by adding a small quantity of binoxide of manganese. Care must be taken not to add it in excess, for in this case it would communicate a violet color to the glass. The binoxide, Mn O_2 , when added in small quantity, is converted into protoxide, Mn O ; but if any excess has been employed, it becomes reduced at a red heat to sesquioxide, $\text{Mn}_2 \text{ O}_3$, and produces a deep amethystine red glass.

The *silicates of the oxides of lead* are the more fusible in proportion to the greater amount of the base. With equal equivalents, the silicate of lead, $\text{Pb O} +$

Si O₂, melts at a red heat. In fact, oxide of lead exerts a directly opposite action to alumina, being a prominent ingredient in the easily fusible varieties of glass, which are also characterized by great softness, a high brilliancy, perfect absence of color, and by the property of refracting light more powerfully than any other kind. The silicates of the oxide of zinc present analogous properties.

Baryta also exerts a similar, although less energetic action than lead.

These different silicates react on one another, and reciprocally modify each other; in composition, they become more stable, less fusible, and less subject to crystallize. Hence the advantage of the complex proportions employed in the glass and crystal manufactories.

When *boracic acid* is added, it forms boro-silicates, often more fusible, more ductile, easier to work, and producing less waste, especially in table-ware and plate-glass manufacture. M. PAYEN remarks that the experiments undertaken by MM. MAES and CLEMENDOT on crystal, with a base of oxide of zinc, yielded products remarkable for their whiteness, their transparency, their hardness, and the brilliant reflection of their cut faces.

In the words of KNAPP, it follows, as a general conclusion, from what has been stated, that those varieties of glass which possess the highest degree of lustre and power of refraction, will also be the softest—that is, the most easily scratched. They are likewise those which exhibit the highest specific gravity—from 2·8 to 3·6—and, as might be deduced from that circumstance, they—at least as far as the colorless glasses are concerned—are those which contain bases with a very high atomic weight—oxide of lead, baryta. Those bases, on the contrary, which render the glass hard and durable, appear to produce little lustre or power of refraction. The specific gravity of these varieties lies between 2·37 and 2·56. Strictly speaking, the alkalis, lime, and oxide of lead, are the only bases expressly contained in the mixture for the manufacture of glass, without reference to the different coloring and decoloring matters. Magnesia sometimes accompanies the lime, and enters, but in small quantity only, into the composition of the glass. Alumina and oxide of iron are, in like manner, only casual constituents, being contained as impurities in the other ingredients. Even in those cases where these two bases enter in large quantities into the composition of glass, they are never expressly added to the mixture; but are always derived from the impure materials. Thus, in the manufacture of ordinary bottle-glass, where color is of no moment, substances containing iron and alumina are employed. The origin of the small quantity of alumina which is found in glass that should properly be free from it, must be traced to the sides of the pots or crucibles in which the glass has been fused.—*Knapp*.

The metallic oxides which have not been mentioned, as those of gold, silver, copper, give rise to a great variety of intense colors, and are consequently used in the manufacture as pigments.

Commercial varieties of Glass.—Before proceeding to a more minute inquiry into the physical and chemi-

cal properties of glass, as these are affected by differences either in the ingredients or their properties, or in the processes followed, it will be proper to place before the reader a summary view of the characters and composition of the different varieties of glass, as preliminary to a more detailed exposition, not only of the special properties, but also of the special manufacture of each of these varieties.

There is much difficulty in dividing the glasses according to any definite principle. One of the simplest arrangements is given by TOMLINSON, as follows:—

1. Silicate of potassa and oxide of lead. Examples:—*Flint-glass, crystal, and strass*.

2. Silicate of soda and lime; or silicate of potassa, soda, and lime. Examples:—*Common window, English crown, and plate*.

3. Silicate of potassa and lime. Examples:—*Foreign crown, refractory Bohemian glass*.

4. Silicate of soda, lime, alumina, and oxide of iron. Example:—*Coarse green wine-bottle glass*.

The following arrangement, somewhat similar to that proposed by KNAPP, will form the basis of that adopted in the present article, beginning, as a general rule, with the coarser, and advancing by a pretty regular gradation to the finer or rarer varieties.

1. BOTTLE-GLASS, or what is more properly described by the German term *Hohl-glass*, or *Hollow glass*, comprises all glass worked into the form of vessels or tubes. According to the purity of the *metel*, which is the technical term given to glass in the fused state, this variety is subdivided into different qualities, such as—*Ordinary bottle-glass*, consisting of silica, potassa or soda, lime, alumina, and oxide of iron; *glass used for medicinal bottles*, consisting of silica, soda, lime, some alumina, and a very little protoxide of iron; *white bottle-glass* for bottles or phials, tumblers, tubes—containing silica, soda or potassa, and lime. It is evident, therefore, that under the general term *Bottle-glass* or *Hohl-glass*, are included different vitreous compositions. Its distinguishing characteristic, as applied to ordinary bottle-glass, is the presence of protoxide of iron; and therefore it may be described, in general terms, as a silicate of potassa or soda, of lime, of alumina, and oxide of iron.

2. WINDOW-GLASS, including *English crown* and *cylinder* or *sheet-glass*: this is a silicate of potassa or soda, lime, and alumina.

3. PLATE-GLASS, composed of silica, soda, or potassa, lime, and a little alumina. This variety only differs from the preceding by the greater purity and freedom from color of the materials.

4. FLINT-GLASS, used for grinding, *et cetera*, composed of silica, potassa, and oxide of lead.

5. CRYSTAL, for optical purposes and table-ware, consists of silica or boracic acid, potassa, and more lead than the preceding. In short, it is a simple flint-glass, formed with very pure materials.

6. STRASS, or the substance composing the imitation of precious stones, known as paste, consists of silica, potassa, with a still larger amount of oxide of lead, and colored by various materials.

7. ENAMEL, a silicate and stannate or antimoniate of potassa or soda, and of oxide of lead. It may be other-

wise described as composed of silica, soda or potassa, and oxide of lead,—rendered opaque by oxide of tin or antimony.

8. SOLUBLE GLASS, which is a simple silicate of potassa or of soda, or a mixture of these two silicates.

The manufacture, the distinguishing properties, and the special applications of these different kinds of glass, will be described afterwards. *Strass* and *enamel* have been already treated under the latter head, and will, therefore, be only briefly alluded to in the present article. The *soluble glass*, which is used only for special purposes, such as a protective varnish for pictures, a fireproof coating for building-materials, *et cetera*, but its character and applications will be stated in a future page. In the meantime, the following tables, which are given by KNAPP, with notes by RICHARDSON and RONALDS, will be found useful for reference, as showing the proportional composition of the more important glasses according to different analysts of high authority:—

BOTTLE-GLASS.

Variety of Glass.	Analysts				
	Berthier		Dumas		
	1.	2.	3.	4.	5.
Silica,	60.0	60.4	59.6	53.55	45.6
Soda,	3.1	3.2	—	—	—
Potassa,	3.1	3.2	3.2	5.18	6.1
Lime,	22.3	20.7	18.0	29.22	28.1
Magnesia,	—	0.6	7.0	—	—
Baryta,	—	0.9	—	—	—
Oxide of manganese,	1.2	—	0.4	—	—
Alumina,	8.0	10.4	6.8	6.01	14.0
Oxide of iron,	4.0	3.8	4.4	5.74	6.2
Oxide of manganese,	—	—	—	—	—
Relation between the oxygen of the acid, and the total amount of oxygen contained in the bases,	5:2	?	7:3	2:1	1:3
Relation between the oxygen in the bases with one equivalent of that element, and that contained in the bases with three equivalents of oxygen,	4:3	?	2:1	2:1	1:1

No. 1—Glass from Souvigny. No. 2—From St. Etienne. No. 3—From Epinac. No. 4—From Sèvres, near Paris. No. 5—From an unknown glass-house, but of French manufacture.

BOHEMIAN GLASS.—The Bohemian flint-glass is distinguished from the others by containing no lead.

Mr. ROWNEY has lately analysed the Bohemian hard glass tubing, so indispensable to chemists in the prosecution of researches in organic chemistry, and finds it to be essentially a silicate of lime and potassa, in which the oxygen in the silicic acid is to that contained in the bases as 6 to 1. Analysis yielded:—

Silica,	73.0
Potassa,	11.5
Soda,	3.0
Lime,	10.5
Magnesia,	—
Alumina,	—
Sesquioxide of iron,	2.0
Oxide of manganese,	—
100.0	

It may, however, be remarked, that this tubing is by no means of uniform composition, as all who have been much occupied with organic analysis will have found to their cost; some tubes being much more fusible than others.

The opal is very similar to hyalite, *muller glass*, a hydrate of silica. The composition is remarkable: it is a simple silicate of potassa, which, from being imperfectly melted, remains semi-transparent, with pieces of quartz dispersed through the mass. It does not attract moisture, and is not attacked by boiling water. It differs from FUCH's soluble glass, by containing ten per cent. more silica.

The Venetian contains also traces of magnesia and phosphoric or boracic acid; the crystals appear disseminated through the mass, which is of a yellow tint, and transparent in thin sheets. The tin and iron obviously assist in the formation of the crystals of metallic copper, after which the tin becomes silicate of the protoxide, otherwise the glass would become opaque.

MEDICINAL GLASS.

Variety of Glass.	Analyst—Berthier.			
	1.	2.	3.	4.
Silica,	71.6	62.5	69.6	62.0
Soda,	—	—	3.0	16.4
Potassa,	10.6	10.5	8.0	—
Lime,	10.0	16.2	13.0	15.6
Magnesia,	—	—	0.6	2.2
Alumina,	3.0	4.5	3.6	2.4
Oxide of manganese,	0.3	1.2	—	—
Oxide of lead,	1.5	2.5	1.6	0.7
Relation between the oxygen of the acid and the total amount of oxygen in the bases,	6:1	7:2	9:2	5:1
Relation between the oxygen in the bases with one equivalent of that element, and that contained in the bases with three equivalents of oxygen,	2:1	7:3	3:1	9:1

All the varieties were of French manufacture.

DIFFERENT VARIETIES OF WHITE GLASS.

Variety of Glass.	Analysts				
	Berthier	Gron.	Dumas	Berthier.	Dumas.
	1.	2.	3.	4.	5.
Silica,	71.7	71.6	69.4	69.2	62.8
Soda,	12.7	11.0	11.8	15.8	22.1
Potassa,	2.5	—	—	3.0	—
Lime,	10.3	10.0	9.2	7.6	12.5
Magnesia,	—	2.3	—	2.0	—
Oxide of manganese,	0.2	0.2	—	—	—
Alumina,	0.4	2.2	9.6	1.2	2.6
Oxide of iron,	0.5	3.9	—	0.5	2.6
Relation between the oxygen of the acid, and the total amount of oxygen in the bases,	6:1	6:1	4:1	4:1	5:1

1. Specimen of a goblet from Neufeld in Bohemia. 2. Specimen from the same place. 3. Bohemian glass. 4. Specimen of easily fusible French glass tubing. 5. Specimen of crown-glass.

WINDOW-GLASS.

Variety of Glass	Analysts								
	Dumas.							Richardson	Cowper.
	1.	2.	3.	4.	5.	6.	7.	8.	9.
Silica,	69.65	69.25	68.55	68.65	68.5	68.0	69.0	66.37	71.4
Soda,	15.22	11.30	12.88	17.70	13.7	10.1	11.1	14.23	15.0
Lime,	13.31	17.25	16.17	9.65	7.8	14.3	12.5	11.86	12.4
Alumina,	1.82	2.20	2.40	4.00	10.0	7.0	7.4	8.16	0.6
Relation between the oxygen of the acid, and the total amount of oxygen in the bases,	4 : 1	4 : 1	4 : 1	4 : 1	7 : 2	7 : 2	7 : 2	7 : 2	9 : 2

The numbers from 1 to 6 are of French origin; numbers 7, 8, and 9 are English.

The specimen was analysed by COWPER, manufactured by Messrs. CHANCE of Birmingham, and is remarkable for containing more silica and less alumina than any of the other varieties. Mr. COWPER also found 0.3 oxide of iron, and 0.3 oxide of manganese in this sample.

PLATE-GLASS.

Variety of Glass	Analysts				
	Berthier	Townsend	Dumas.	Berthier	
	1.	2.	3.	4.	1.
Silica,	72.0	76.0	75.0	73.85	68.6
Soda,	—	—	—	5.50	6.9
Potassa,	17.0	17.0	17.5	12.05	8.1
Lime,	6.4	6.0	3.8	5.60	11.0
Magnesia,	—	—	—	—	2.1
Alumina,	2.6	—	2.8	3.50	1.2
Oxide of manganese, ..	—	—	—	—	0.1
Oxide of iron,	1.9	1.0	—	—	0.2
Relation between the oxygen in the acid, and the total amount of oxygen in the bases,	6 : 1	?	7 : 1	7 : 1	5 : 1

The last specimen was Venetian, the others were French glass.

CRYSTAL.

Variety of Glass	Analysts				
	Berthier.		Dumas	Faraday	
	1.	2.	3.	4.	5.
Silica,	59.2	56.0	51.4	56.0	51.93
Potassa,	9.0	6.6	9.4	8.9	13.67
Lime,	—	—	—	2.6	—
Alumina,	—	1.0	1.2	—	—
Oxide of lead,	28.2	34.4	37.4	32.5	33.28
Oxide of manganese, ..	1.0	—	—	—	—
Oxide of iron,	0.4	—	0.8	trace	—
Relation between the oxygen of the acid, and the total amount of oxygen in the bases,	8 : 1	8 : 1	6 : 1	6 : 1	6 : 1

1. From London, intended for optical instruments. 2. From Veneche in Belgium. 3. From Newcastle. 4. Of unknown origin. 5. From England.

The oxide of lead which is used in the manufacture of crystal, is not the protoxide commonly known as *massicot*, and represented by the formula PbO , but *minium*, which is a sesquioxide, Pb_2O_3 ; for, as BARUEL remarks, one may depend on the latter not being mixed with metallic lead, which almost necessarily happens with the massicot of commerce. The object of employing oxide of lead in this kind of glass is to increase the density, and, consequently, the refractive power, which gives the glass a peculiar lustre or brilliancy.

FLINT-GLASS, STRASS, AND ENAMEL.

Variety of Glass	Analysts			
	Faraday.	Dumas	Dumas	Dumas
	Flint-glass from Cumbria	Strass manufactured by Droult W. Ireland	Enamel	
Silica,	41.3	42.5	38.5	31.6
Potassa,	11.75	11.7	7.9	8.3
Lime,	—	0.5	—	—
Alumina,	—	1.8	1.0	—
Oxide of lead,	43.05	43.5	53.0	50.3
Oxide of tin,	—	—	—	9.8
Relation between the oxygen in the acid, and the total amount of oxygen in the bases,	9 : 2	4 : 1	7 : 2	7 : 3

The following analyses by PELIGOT are given by RICHARDSON and RONALDS as quite recent:—

	Bohemian glass	Bohemian opt. glass	Yveton flint-glass	Bohemian mirror-glass
Silica,	76	80.9	67.7	67.7
Potassa,	15	17.5	5.5	21.0
Soda,	—	—	7.1	—
Lime,	8	7	8.9	9.9
Alumina,	1	8	—	1.4
Oxide of tin,	—	—	2.3	—
Oxide of lead,	—	—	1.1	—
Copper,	—	—	metallic 3.9	—
Oxide of iron,	—	traces	3.5	—
	100	100.0	100.0	100.0

Chemical Constitution of the Different Glasses.—From a careful inspection of the preceding tables, it will be seen that all the constituents of the different varieties of glass are in a state of chemical combination. It follows that the individual constituents must be united in equivalent proportions; and though these relations are sometimes difficult to trace, in consequence of different oxides replacing each other, still, the regularity of the composition is always shown by the existence of a simple relation between the collective amount of oxygen in the bases, and that contained in the silica or silicic acid. The combination in definite proportions is rendered more obvious, as KNAPP observes, when the empirical formulæ are deduced from the composition in 100 parts. Thus, by referring to the numbers of the columns in the preceding tables, the composition in 100 parts of each of the glasses specified, will be represented as follows:—

Bottle-glass, No. 5,	corresponds to	$KO + 8 CaO + ? Al_2O_3 + F_2O_3 + 8 SiO_2$;
Window-glass, No. 2,	"	$8 NaO + 5 CaO + 12 SiO_2$;
Plate-glass, No. 1,	"	$2 NaO + CaO + 8 SiO_2$;
White Crown-glass, No. 5,	"	$KO + CaO + 8 SiO_2$;
Crystal, No. 2,	"	$KO + 2 PbO + 8 SiO_2$;
Flint-glass, No. 2,	"	$6 KO + 9 PbO + 20 SiO_2$;
Strass, No. 1,	"	$8 KO + 9 PbO + 16 SiO_2$; <i>et cetera</i> .

KNAPP further justly remarks, that although more probable suppositions may be formed with reference to the manner in which the silica is divided amongst the bases, and although the preceding calculations do not lead to any rational formulæ, yet the knowledge of the empirical composition for any species of glass, as represented in the examples above given, is nevertheless a very valuable guide in mixing the ingredients for its manufacture, and of great service in improving or correcting the prescribed rules.

Comparative Fusibility of the Glasses.—Under the influence of a cherry-red heat and upwards, the different kinds of glass are all capable of being first softened and then undergoing a complete fusion. At the same time, the difficult fusibility of the bi and tri silicates, or those in which the acid preponderates, and the opposite properties of those which contain a larger proportion of base, are very important facts in connection with the manufacture of glass. Silicic acid *per se*, is perfectly infusible in every furnace, but it acquires the property of fusibility in a greater or lesser degree, according to the quantity of base with which it is mixed. Glass-makers, in short, call all the bases *fluxes*, and are well aware that the work is facilitated and fuel saved by increasing the amount of flux in the mixture; but, at the same time, they know that the addition of flux cannot exceed a certain limit without detriment to the durability of the glass. When glass is attacked by reagents, under ordinary circumstances, it is always a result of the removal of base; but this is a subject for future consideration. As already stated, glasses with a lead base are the most fusible, and the more so in proportion as they contain a more considerable quantity of oxide of lead. Common glasses, on the contrary, are less so, the more lime and alumina they hold. Thus, strass, flint-glass, and crystal, are more fusible than common or window-glass, and the latter is a little more so than bottle-glass.

Imperfect Fluidity of Glass.—The possibility of casting or moulding glass, as well as its purification, depends upon the fact that at very intense heats the so-called metal is tolerably fluid, though still possessing a consistence which may be compared to that of weak sirup. In this state the heavier impurities are enabled to subside to the bottom, while the bubbles of gas, which too often form flaws in glass, rise by their levity to the surface. At a brisk red heat, on the contrary, the metal is only in a semi-fluid state, and on this peculiar and valuable property depends the possibility of working it into every variety of form. In this state it is an exceedingly tough, thick mass, possessing great ductility, and capable of being drawn out into the finest threads, or blown into the form of the thinnest hollow spheres. In short, it is evident that the usual methods of working glass by *blowing*, and of soldering different pieces together by simple pressure or contact,

would be quite impracticable, unless the mass possessed these properties.

BRITTLENESS.—When glass has been heated to the softening point, and exposed to a rapid cooling, it is very brittle; when, on the contrary, it is submitted to a slow cooling, it becomes capable of resisting pretty severe shocks without breaking, and it stands equally well sudden variations of temperature. These phenomena have been compared to the tempering of steel; and although the explanations which have been given of them are not quite satisfactory, yet it will be necessary to enter into some details, on account of the practical importance of the subject. The metamorphosis has been attributed to unequal crystallization. It will be seen afterwards that the particles of glass always exhibit in the fluid state a tendency to arrange themselves in a regular manner, and form crystals. Now, when the mass is cooled suddenly, no time is allowed the particles to follow this tendency, and they are forced, as it were, against their inclination to remain in that relative position towards each other which they assumed during the working, or, in other words, to form an amorphous mass. This forced relative position of the particles is greatest where the glass has been rapidly cooled; the interior of the mass is, therefore, not so subject to it as the surface, and this latter also contracts in a greater degree. The outer layers are, consequently, in a state of tension, with reference to those in the interior. It is obvious, from these facts, that there must be a want of uniformity in the attractions of the particles of glass for each other; that a tendency to subvert the force of cohesion has been induced, which the slightest impulse from without will be sufficient to call into action. This circumstance perfectly explains the brittle nature of glass, which sometimes rises to a very extraordinary degree. For example, if one takes a little melted glass, and allows it to fall, drop by drop, into cold water, each drop will suddenly solidify, and will take a form generally spheroidal or ovoidal, terminated by a tail which ends in a rapidly tapering point, *a*, as represented in Fig. 135. The surface of this drop of glass is harder than ordinary. But by merely breaking off the point, the

Fig. 135.



tension is called into play, and the whole mass flies to pieces, or rather is instantly converted into a fine powder, with a slight detonation. These little articles are known, from their great brittleness, under the name of *Rupert's drops*.

The effect is explained by DUMAS, by supposing that by the immersion in cold water the surface of the glass is suddenly solidified, the central parts being still fire-

red, and consequently much dilated. When these last become solidified and cooled down, they must have retained points of adherence to the surface, and consequently occupy a larger volume than that which agrees with the temperature to which they are reduced; the central molecules are, therefore, more distended than usual, and exert a powerful contracting force on the surrounding parts. At the instant when a part of the envelope or outer portion is broken, the molecules which had been retained by it briskly contract, draw in with them all the others, and thus determine a multitude of points of rupture; as this effect is instantaneous, each fragment is shot with force, and drives the air before it; this fluid, therefore, undergoes a sudden dilatation and contraction, from which results the detonation that is heard.

The same effect is produced under another form, in what is termed the *Bologna* or *philosophical phial*—Fig. 136. This is a kind of short tube, thick, and closed

Fig. 136.



at one end, which is obtained at crystal manufactories, by blowing a small portion of glass to judge of the state of the metal in the pots during the melting. These tubes are very thick, for they must be sufficiently so to allow of appreciating exactly the tint of the glass. They are exposed to a rapid cooling, because the object which they are intended to serve does not require that any care should be taken in that respect.

This cooling is even accelerated by shaking in the air the rod which supports the small tube. The latter is then, in point of fact, in a state very analogous to that of the Rupert drops, and DUMAS explains their remarkable brittleness in the same manner. The interior parts have undergone a slow, and the exterior parts, on the contrary, a rapid cooling; and when these tubes are struck, even very strongly, on the outside, they do not break, while the slightest stroke on the inside is sufficient to make them fly in pieces, with a detonation similar to that which occurs in the case of the Rupert drops. A small marble, a bit of glass allowed to fall into the interior of the tube, is sufficient to make it burst asunder.

Phenomena more or less analogous to these happen with glass vessels of some thickness, which are sold for common uses. By slight variations of temperature, such as occur when they are carried from a room without a fire into a warm room, it sometimes happens that these glasses suddenly burst without any apparent cause. It is obvious, that the thicker the glasses, the more readily will effects of this kind be produced. Tubes of glass somewhat thick, and especially those which are of unequal thickness, are also very subject to split, and usually the crack is prolonged through the whole length of the tube. But glass tubes are not submitted to that particular operation, the object of which is to render glasses less liable to break by sudden changes of temperature. This operation is termed *annealing*, and consists in submitting the glass to a very slow refrigeration. The details of the process will be described in connection with the general arrangements of the glass-house and its furnaces, among which the *annealing arch* or oven takes an important place.

It would seem that the ordinary annealing of glass, whether it be that the operation is badly performed, or that it has not a durable effect, always leaves something to be desired. For some articles, a method of annealing is employed which is very simple, but, at the same time, expensive, if required to be applied on a large scale. It consists in placing the glass vessels in a trough or pan, taking the precaution to separate them by a little hay or straw. The vessels and the pan are filled with water, and the liquid is brought to ebullition. The whole is then left to cool slowly. The vessels thus treated are, so to speak, insured against any rapid change of temperature, comprised within the interval of 180° Fahr., or thereabouts. By using a bath of water charged with some salt, an oil-bath, or a bath of fusible alloy, this method might be extended to higher temperatures.

The efficacy of the process rests on the great difference which exists between the conducting power of air and that of liquids. There is no doubt that in the operation of annealing in the air, different points of the surface are cooled at different rates, a circumstance which can never occur when the annealing is effected under a liquid mass. It is well known in laboratories, that vessels which have accidentally undergone an annealing of this kind, are thereby rendered very fit to support, without breaking, rapid changes of temperature.

On the whole, although the brittleness of glass is not entirely obviated by the most careful annealing, yet it is so modified that the vessels, with a little care, can be used for all ordinary purposes. Sudden change of temperature, or partial application of heat, will cause the fracture of unannealed glass quite as surely as a blow, by expanding it more at one part than another.

DEVITRIFIED, OR SEMI-CRYSTALLISED GLASS.—As excessive brittleness results from the sudden cooling of glass, so, on the other hand, when the fused metal is cooled too slowly, the amorphous state entirely disappears, the mass assumes a crystalline structure, and other changes occur which are termed *devitrification*. If the glass contain different bases, a partial separation takes place; the silica divides itself between the bases, and thus forms compounds of definite proportions which crystallize separately. In this case the intimate mixture of the materials which constitute the true glass is destroyed; the glass becomes *very hard, fibrous, opaque, much less fusible, a better conductor of electricity and of heat*. The first glass of this kind was produced and described by RÉAUMUR, and was termed by him *devitrified glass*.

The devitrification of glass is a general phenomenon, which exhibits itself in all kinds of glass, but especially in glass with several earthy bases, and more difficultly in plumbiferous glasses, or glasses simply alkaline. It is almost always produced by melting the glass, and allowing it to cool very slowly, or else by heating the glass to the softening point, and submitting it to a prolonged heat and a graduated cooling. The operation succeeds better in bottle-glass than in any others; then comes common green glass, next white glass, then simple glass, with a soda base; after this, flint-glass, and, lastly, simple glass, with a potassa base.

This property exerts so great an influence in the manufacture of glass, that it is difficult not to make an immediate application of it. It explains, indeed, why, in the making of bottles, so much care is taken to avoid the repeated reheating of the mass which is to be formed into that article. It would be thoroughly devitrified in a few seconds; the glass would become hard, difficult to fuse, and would present a multitude of solid grains disseminated in a matter still soft. One sees in the same manner why green glass, and even common white glass, and, still more so, bottle glass, can only be shaped by the lamp of the enameller when the work is performed with the necessary despatch. If he works so slowly that he is obliged to reheat several times the glass tube which he is blowing, the mass devitrifies, and all the phenomena show themselves which have just been described. In vain does he then try to blow a bulb—all the force of his lungs will not avail; the glass is no longer soft. Besides, the material then becomes rugous, semi-opaque, and almost infusible.

One can understand, on the same principles, how important it is to select with care glasses intended to be used in large and thick masses, such as those designed for the making of lenses for large optical instruments. The cooling of such masses is necessarily very slow, which induces the devitrification of the glass. It is almost impossible to succeed, therefore, except with glass having a base of lead and potassa, and glass with a base of potassa and lime. Indeed, these two kinds of glass, which constitute *flint* and *foreign crown* glass, are employed exclusively on the Continent for the making of objectives for achromatic telescopes.

The devitrification of glasses is a phenomenon of the greatest interest, and to which the attention of glass-makers cannot be too much directed. It will appear still more worthy of consideration when it is shown that, in virtue of its properties, devitrified glass is capable of replacing porcelain in almost all its uses. Thus, for the requirements of chemistry, one may make tubes, retorts, receivers, capsules, which resist the fire as well as vessels of porcelain, which are as impermeable as common glass, which resist acids very well, and which, in fine, may be obtained in a single piece, under a thousand diversified forms, which the moulding of porcelain could only furnish with difficulty. This is a business to be created, and a very important business, for it would furnish vessels of a wholesome, elegant ware, and at a comparatively low price.

To effect the devitrification of glass, RÉAUMUR selected common bottle or green glass. He filled the vessels with a mixture of roasted sulphate of lime and white sand, reduced to fine powder. He introduced them into an earthen box, which itself was filled with a similar mixture, taking care that the vessels were well isolated from each other, as well as from the sides of the box, the empty space being occupied with the plaster and sand. The box, thus prepared, fitted with a lid and luted, was carried into a pottery furnace, and left to itself during the whole duration of a firing. At the end of that time the glass was entirely devitrified.

The fracture of this glass is silky, and an attentive examination of it is sufficient to show how the phenomenon is produced. In fact, exactly in the middle of its thickness, the glass presents a brown line, and it is at this point that an infinite number of small crystalline needles meet, proceeding from the exterior and interior surface of the vessel. These needles, perfectly parallel to each other, are perpendicular to the surface of the glass, as well as to the plane passing through the line of junction, which itself follows all the variations of form in the glass. It may be added, that in glasses imperfectly devitrified the two surfaces exhibit similar needles, but too short to meet, and, consequently, separated by a greater or less breadth of common glass, which occupies the middle of the thickness of the plate or vessel. It is evident, therefore, that whatever cause determines the crystallization of the glass, acts first on the surfaces, and afterwards penetrates to the middle, till the crystals setting out from the two opposite points come to meet.

M. DARTIGUES was convinced that the gypsum and sand mixture was not indispensable, and that bottle-glass, heated only to redness during some hours, was entirely devitrified. Nevertheless, the potassa volatilizes during the devitrification, which indicates the utility of a silicious cement, which then performs the part of an absorbing body in the manner of the sulphuric acid in LESLIE's experiment for freezing water in a vacuum.

RÉAUMUR did not well understand the theory of the phenomenon of devitrification, and, subsequently, KEIR, PAJOT-DES-CHARMES, and some other observers, in examining and describing the crystallizations which sometimes occur in glass, were not more successful in perceiving the intimate connection between these two classes of facts. The researches of DARTIGUES as well as those of FLEURIAU DE BELLEVUE, ultimately placed beyond doubt the complete identity of these two phenomena.

Devitrification is therefore a crystallization of glass. Experience proves that glass, slowly cooled, almost always crystallizes when the passage from the liquid to the solid state is effected so gently as to allow the requisite molecular arrangements to take place. But it appears that, by applying this idea in an absolute manner to the devitrified glasses of RÉAUMUR, a grave error would be committed, which analysis teaches one to avoid. There exist, in fact, two distinct kinds of devitrified or crystallized glasses, resulting from different actions. 1. The first class embraces glasses which, by means of a prolonged heat, and sometimes by the aid of a suitable lute or cement, have arrived at a state of homogeneous combination, and have taken the crystalline form, losing some of their constituent principles. 2. The second kind comprises glasses which, by means of a solidification very slowly effected, are divided into two or more different compounds, some of which have preserved the uncrystallized state, while others have taken a regular crystalline form.

It is possible to discover by analysis what takes place in these two cases. The manner in which RÉAUMUR effected the devitrification has been already stated. In proceeding to examine its results, DUMAS

made the following analysis of a tube of bottle-glass devitrified by M. D'ARCET at the glass-work of La Garre at Paris :—

	Centesimally Oxygen.	
Silica,.....	52.0	= 27.0
Alumina,.....	12.0	= 5.6
Sesquioxides of iron and manganese, ..	6.6	= 2.0
Lime,.....	27.4	= 7.6
Loss, or potassa,.....	2.0	= 0.2
	100.0	42.4

Comparing this analysis with that of common bottle-glass, already given at page 191, it will be seen that the amount of the potassa is reduced to at least one-third or a half of the ordinary quantity. Moreover, this analysis shows that the sample analysed consisted of one equivalent of sesquisilicate of iron or of alumina, and one equivalent of bisilicate of lime or of potassa.

It is far from probable that the same result would be obtained for all analogous glasses, as regards the state of saturation of the silicates, or their proportion to each other; but it is certain that the potassa almost entirely volatilizes by the devitrification effected in RÉAUMUR's manner, and that the other products arrange themselves, either to constitute a single silicate, or to form several of them, which remain mingled.

D'ARCET found, it is true, that bottle-glass was devitrified without changing its weight. That might happen, in fact, when the oxygen, absorbed by the transition from the oxide of iron to the sesquioxide, is equal in weight to the potassa volatilized.

The chemical changes observed in the devitrification of *bottle-glass* consist, therefore,—1st. In the loss of a part or the whole of the potassa. 2nd. In the passing of a part or the whole of the protoxide of iron and of manganese to the state of sesquioxides. 3rd. In the formation of one or more definite and crystallized silicates, by means of the remaining products.

The second process of devitrification, which consists in the mass being broken up into different chemical compounds, presents itself sometimes alone, but often simultaneously with the preceding. DUMAS mentions

the curious results of an experiment made on the large scale, at the glass-works of Choisy-le-Roi, in which this process was observed to be quite distinct from the preceding. A glass was formed with 100 of sand and 40 of carbonate of soda, perfectly pure and dry. This glass being cooled rapidly, was transparent like ordinary glass. It was re-melted, and submitted to a slow cooling, that the solidification might take place tardily. A glass was thus obtained which was milky, grainy, and evidently devitrified in some places. The devitrified parts were re-melted, and rapidly cooled again after the melting, which furnished common glass once more. This glass, by a new fusion and a prolonged cooling, gave a glass better devitrified than it was the first time. Lastly, the portions which exhibited the most perfect devitrification, being again melted and quickly cooled, again yielded a glass endowed with its ordinary characteristics.

This remarkable experiment sufficiently proves that, in the slow solidification of glass, a division of its elements is determined, in consequence of which a definite silicate crystallizes, and thus separates from the remaining mass.

DUMAS states that there existed in the cabinet of the Polytechnic School at Paris, a mass of glass detached from the bottom of a crucible. At the surface of it was an opaque crust, white, crystallized in needles, and of a uniform thickness of one or two lines. All the rest of the mass was of a perfect transparency, but in the interior of it might be observed a multitude of white and opaque prisms, similar to the exterior crust; partly isolated; partly collected in groups of two, three, four, *et cetera*, and forming stars; in some cases more numerous still, and then forming spheroids. The devitrification was therefore effected in this case at the surface, in consequence of the evaporation of the potassa, and in the mass itself, in consequence of the separation which resulted from a slow cooling. Subjoined is the analysis of the two kinds of glass contained in this piece by DUMAS, and that of another specimen by KERSTEN:—

	Kersten.				Dumas			
	Crystalline portion.		Vitresous portion.		Crystalline portion.		Vitresous portion.	
		Oxygen.		Oxygen.		Oxygen.		Oxygen.
Silicic acid,.....	58.8	30.54	60.39	31.40	68.2	35.46	64.7	53.64
Alumina,.....	3.3	1.54	6.10	2.84	4.9	2.28	3.5	1.63
Lime,.....	20.2	5.77	13.40	3.83	12.0	3.43	12.0	3.43
Protoxide of iron,.....	3.5	0.80	3.10	0.70	—	—	—	—
" manganese,.....	4.2	0.93	2.20	0.49	—	—	—	—
Magnesia,.....	0.5	0.19	0.40	0.15	—	—	—	—
Potassa,.....	2.7	0.45	} 14.41 3.05 {		—	—	—	—
Soda,.....	5.5	1.40			1.49	3.81	19.8	5.06

It is evident that, in the specimen analysed by DUMAS, the potassa had been separated from the glass at the instant of crystallization. It is equally manifest that while no simple proportion can be traced between the elements of the transparent glass, one observes, on the contrary, in the crystallized glass a clear and well-defined composition; for the oxygen of the alumina is about one-third of that of the potassa and of the lime, and the oxygen of these three bases is pretty exactly

the fourth of that of the silica. It is, therefore, a compound of one equivalent of quadrisilicate of alumina, and of three equivalents of quadrisilicate of soda or of lime, which corresponds to the composition of ordinary window-glass. More distinctly, in the specimen analysed by DUMAS, the oxygen in the silicic acid is to that of the alumina, and to that of the other bases together, in the following ratios:—

In the crystalline portion, as $35.46 : 2.28 : 7.24 = 18 : 1 : 3$
 In the vitreous matrix, as $33.64 : 1.63 : 8.49 = 15 : 1 : 5$

For the former, $M_2 O_3, 6 Si O_2 + 9 (M O Si O_2)$
 For the latter, $M_2 O_3, 3 Si O_2 + 15 (M O Si O_2)$

In the specimen analysed by KERSTEN, the relations of the oxygen were as follow:—

In the crystalline portion, as $80.54 : 1.54 : 9.54 = 21 : 1 : 6$
 In the vitreous matrix, as $81.40 : 2.84 : 8.22 = 12 : 1 : 3$

For the crystalline portion, $M_2 O_3, 3 Si O_2 + 9 (M O Si O_2)$
 For the vitreous matrix, $M_2 O_3, Si O_2 + 18 (M O Si O_2)$

These relations, as deduced from both analyses, render it probable that the two portions were distinct chemical compounds. It may, therefore, be assumed that when the glass is submitted to a slow solidification, there occurs a separation of the least fusible definite compound to which its elements can give rise—the latter then taking the crystalline state.

If the analyses of different glasses previously given had not solved the question, these last two would suffice to demonstrate that all the glasses are silicates in definite proportions, or, at least, mixtures of different definite silicates, dissolved the one by the other. Hence it may be inferred, that by sufficiently prolonging the time of the solidification of a vitreous mass, it would be possible to separate successively compounds more and more fusible, the alkaline base concentrating more and more in the successive residues. And hence, also, may be conceived what takes place in the solidification of lavas, which have so much analogy with the products now under consideration, and an explanation may be given of the formation of natural crystals, so diversified as they appear in their mass.

To sum up—in the words of DUMAS, to whom the Editor is chiefly indebted for what has been stated on this interesting subject—*devitrification is a crystallization of glass, due to the formation of definite compounds infusible at the temperature existing at the instant of the devitrification.* Sometimes this infusibility is produced by the volatilization of the alkaline base; sometimes by a simple division or separation, the alkali then passing into that portion of the glass which preserves the vitreous state. All glasses may therefore be devitrified, for all glasses are capable of passing to the state of definite, and consequently crystallizable, silicates. Glasses which contain at the same time indifferent oxides and basic oxides will devitrify better than others, by the tendency which the indifferent silicates and basic silicates have to combine in definite proportions. Lastly, devitrified glasses will possess very variable properties, for their composition itself will differ completely, according to the nature of the glasses and the circumstances of the devitrification. Thus, sometimes the devitrified glass will be crystallized in needles of considerable size, as happens with window-glass; sometimes it will be crystallized in very fine needles, or even simply transformed into an opaline mass, without appearance of crystals, as in the case of bottle-glass.

Specific Gravity of different kinds of Glass.—It is evident that the specific gravity of glass must depend on its composition. Alkaline calcareous glasses are the lightest; bottle-glass comes next; then plumbiferous

glasses. The following are the results of some experiments:—

	Specific Gravity.
Bohemian glass,.....	2.386
Crown-glass,.....	2.487
Saint Gobain plate-glass,.....	2.488
Cherbourg plate-glass,.....	2.506
Window-glass,.....	2.642
Bottle-glass,.....	2.732
Crystal, or common flint-glass,.....	2.9 to 3.255
Optical flint-glass,.....	3.3 to 3.6

The Editor finds several kinds of glass to give the following specific gravities:—

White flint-glass,.....	3.000
Bottle, common green,.....	2.715
Green-glass, St. Helen's,.....	2.654
Crown-glass,.....	2.520
Leith crystal,.....	3.189
Plate-glass, Ravenhead,.....	2.439

As regards crystal or flint-glass, the density may suffice to give a pretty exact idea of its composition. It is not so with the other kinds of glass, the differences of density of their constituent principles not being sufficiently marked.

LOYSEL attempted to establish formulæ which might permit of passing from the density to the composition, but they are altogether inapplicable. Little, if any, advantage is to be had from them, even for glasses containing lead. These relations vary from so many causes, that, to establish them in a positive manner, it would be necessary to limit oneself to certain glasses, and to deduce them from experiments so delicate and so numerous, that it would be better to have recourse to the ordinary methods of chemical analysis, the results of which will always be more reliable.

CHEMICAL PROPERTIES OF GLASS.—Among the chemical properties of glass, there are some which merit an attentive examination. DUMAS classes them as follows—namely, the effect of the air or of deoxidizing bodies; that of water; that of acids; and that of bases.

Action of Air or Oxygen.—Air or oxygen, cold or hot, provided they are dry, exercise no action on glasses. It is not so with moist air, as will be seen further on, especially with reference to soluble glass. In this case, however, the reagent is water.

Action of Deoxidizing Bodies.—It is evident that deoxidizing bodies may, on the contrary, act with the aid of heat on glasses which contain oxides of iron or of manganese, and especially oxide of lead. In fact, when plumbous glasses are heated with charcoal, or in a current of hydrogen, they very readily undergo a remarkable alteration. The oxide of lead is reduced, and the metal being set free, communicates to the glass a blackish tint. This effect is even so rapid, that one cannot operate on crystal at the enameller's lamp without blackening it greatly, except particular precautions be used. The plan which succeeds best consists in placing a little soap on the wick of the lamp; the flame suddenly assumes a different appearance, and no longer blackens the crystal. It is probable that the presence of the soap affects the capillarity of the wick, and diminishes the ascent of the oil.

Action of Water.—Water does act more or less on all glasses; and there is a great number which it tends to decompose into a soluble alkaline silicate, and

an insoluble earthy and alkaline silicate. It produces in some sort the same separation which would result from a slow cooling, or from the devitrification of the glass. Window glasses, or those which have an analogous composition, are altered in this manner, and very much so, by boiling water. This was long ago remarked by SCHEELÉ. So much is this the case, that water which is boiled for a long time in glass vessels becomes alkaline and turbid by the portion of earthy and insoluble alkaline silicate which forms the residue of its action, and which, detaching itself from the sides of the vessel, remains in suspension in the liquid. This effect is even so marked on crown-glass, plate-glass, and certain window glasses, that it is only necessary to reduce them to a fine powder, and to put them in contact with cold water, in order to impart to the water an alkaline reaction. Lastly, these same glasses have almost always so much of a hygrometrical property, as to become covered with a thin coating of water when they are exposed to the contact of moist air.

This action of water affords an explanation of a considerable number of phenomena occasionally observed on glasses, and chiefly on those with a base of lime and soda, or potassa. Every one knows that looking-glasses sometimes tarnish in the air. This result proceeds from the deposit of a film of hygrometrical water; the same is observed on the glasses of optical instruments. If the glass is well made, the effect proceeds no further; but if it is too alkaline, the deposited water gradually acts upon its surface, and thus produces a decomposition similar to that above-mentioned; in this case the glass is tarnished beyond remedy, or at least it must be repolished. Sometimes the tarnishing is scarcely perceptible, and yet a great alteration may have been produced on the surface. This is observed when one proceeds to heat the glass; its surface becomes detached in very thin lamellar scales, presenting a great regularity of fracture. The glass then remains completely deprived of its polish, wrinkly, and almost opaque. Glass-tubes, globes, retorts, and even measures or standing-glasses which in laboratories are long exposed to moist air, very often exhibit the same phenomena. In this state the tubes, for example, can no longer be heated at the lamp without losing their polish. Watch-glasses are often observed in the same condition, and even the glasses of optical instruments. It appears, indeed, that glasses which have been polished are more liable to this effect than common glasses. It is well known that glass which has not been polished presents a harder and more brilliant surface, which seems due to the *tempering* it undergoes at the instant of cooling. It is possible, therefore, that polishing renders glasses more readily attacked, by exposing the interior part of the mass, and destroying the hard coat which secured it.

The windows of houses, offices, or public buildings, of an old date, often present a tarnished and unpolished surface, the origin of which must be attributed to a similar cause. When the hygrometrical water has attacked the glass, the slightest changes of temperature cause its surface to splinter, which thus becomes dull, devoid of polish, or at least cracked, and disposed to rise in scales by the least rubbing. This

effect may especially be remarked in the windows of stables; these, after some years, are always so much altered as to exhibit all the phenomena of the decomposition of light produced by thin plates; they become in fact irised, and sometimes in a manner very remarkable for the intensity and purity of the colors. This, however, is chiefly due to the ammonia, developed by the excrement and urine of the animals, attacking the silica. On the contrary, it is the weather or moisture which produces the remarkable alteration observed in old glass that is found in ruins or in tombs. Its surface is sometimes entirely decomposed; it has become opaque, and the slightest rubbing causes it to peel off in thin light pellicles, exhibiting all the colors of the rainbow. When the decomposed part is detached from the outer surface of a phial, one would suppose it to be cut; but it is not so: this appearance is due to the interior layer of the decomposed glass, which, by reason of its perfect opacity, reflects all the light which passes through the part still transparent. One finds here, therefore, but only in greater intensity, all the effects which may be so frequently observed on stable windows.

Action of Alkalies.—Since water *per se* is capable of acting on glass with so much energy, it will readily be conceived that *concentrated solutions of potassa and soda* must be capable of attacking it still more powerfully. This kind of reaction has not been much studied. At a red heat, not only potassa and soda, but all the carbonates and all the bases of that class, combine with the elements of glass to constitute glasses more basic. When carbonate is used, the carbonic acid is expelled. It may even be said that all the oxides not decomposable by heat, when heated with glass, combine with it, and thus form glasses transparent or opaque, colored or colorless, more or less readily acted on than the glass employed, according to the proportions. In general, when the proportion of oxide added is much increased, the glass is rendered soluble in acids. This is what is done in the analysis of glass, when it is heated with carbonate of soda, carbonate of baryta, or oxide of lead.

Action of Acids.—The acids, in their turn, should act on glasses with facility. Among these, the hydrofluoric acid must be classed by itself, its action being quite peculiar. The other acids tend to decompose glass, by seizing on the bases and setting the silica free.

Among the bottle-glasses, there are many which resist the action of wine, and which, nevertheless, are powerfully attacked by the nitric, hydrochloric, and sulphuric acids. Salts of lime, of iron, of alumina, and alum, are formed when sulphuric acid is used. This acid produces in the interior of the bottles crystalline nipples or pustules, the base of which ultimately pierces the vessel; these pustules are sometimes of the size of a bean; in all cases the silica set free assumes a jelly-like appearance.

A bottle-glass too rich in alumina is one of those which the acids most readily attack. DUMAS states that he has seen such glasses, which the bitartrate of potassa contained in the wine attacked so quickly that the alteration was perceptible at the end of a few days.

The salt of alumina produced discolours the wine, and imparts to it a disagreeable taste. The bottle becomes corroded, and a flaky deposit is detached from it. At the same time, crystals of different salts are deposited.

Glasses with a lead base are so much the more easily acted on in proportion as they are too rich in lead. Well-made crystal resists acids well. It is the same with window glasses; when too alkaline they are acted on very easily; when well-made, they resist. Moreover, when a glass loses its polish by heat, one may be sure that it is of a nature to be attacked by acids.

Special Action of Hydrofluoric Acid.—It has been stated that the hydrofluoric acid acts on glass in a special manner; and indeed, as this acid transforms the silica into water and fluoride of silicon, it follows that it must act on all glasses. Its action in fact would be always quick and complete, if the formation of a certain quantity of double fluoride of silicon and sodium, of potassium, or calcium, or lead—double fluorides, which are all insoluble, or only slightly soluble—did not diminish the contact, and, consequently, the effect produced.

The hydrofluoric acid, however, attacks glass rapidly when the action is exerted on a small surface, and much acid is employed. This property has been turned to account to etch glass; the acid is employed in a gaseous or liquid state, according to the occasion and the end proposed. The gaseous acid produces opaque traces; the liquid acid transparent ones. But the subject of etching on glass will be alluded to afterwards.

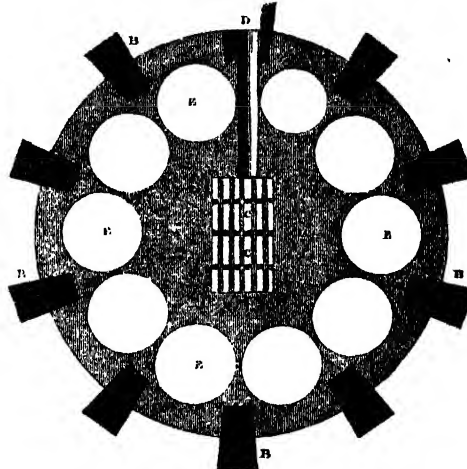
MANUFACTURE OF GLASS.—There are no reliable records of the processes employed by the ancients in the making of glass. But from the time when AGRICOLA described this art, the general arrangement of the furnaces, the mode of fabrication, and the nature of the materials employed, have undergone only modifications of detail, without any change in the general character of the process. No inconsiderable portion of works on the manufacture of glass is usually devoted to the arrangement and construction of the furnaces and pots, the tools employed by the workmen, and the dexterous mechanical operations by which the soft and ductile *metal* is shaped into the various forms that fit it for domestic use and the purposes of science and the arts. These subjects form so important a part of the glass manufacture, that they cannot be entirely omitted in the present work; but the Editor deems it his duty to discuss them as briefly as possible, devoting his principal attention to the chemistry of the manufacture. He will therefore dismiss, in a very few words, the construction of the furnaces, pots, and tools employed.

Glass-house and Furnaces.—The glass-house in which the processes of melting and blowing are performed, is usually built in the form of a truncated cone, open at the top, of sixty or eighty feet in height, and forty or fifty feet in diameter at the base. In the centre of the area is situated the melting furnace, capable of holding from five to ten glass-pots or crucibles for fusing the materials. The grate of the furnace is nearly on a level with the floor of the glass-house; and the *ashpit* or *cave* is a subterranean passage, extending from each side of the furnace to the exterior of the

building, so as to catch the wind from as many aspects as possible. The particular arrangements of the glass-house, and the construction of the furnaces, are somewhat varied according to the kind of glass prepared.

The plan of a flint-glass-house furnace is shown in the annexed engraving—Fig. 137—where the furnace is represented as containing ten pots, E E. There are as many flues, B B, as pots, one flue being placed between every two pots; and immediately abreast of each pot, and

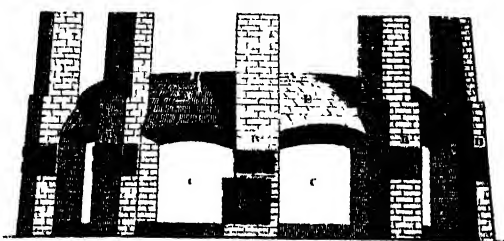
Fig. 137.



between two flues, is an aperture called the working hole, which is used for introducing the raw materials, and taking out the glass or *metal*. The coals are shovelled through a square hole, D, upon the grate, CC, in the centre of the furnace. The grate bars are supported by two strong iron sleepers, and are protected from the intense heat by being previously covered with a layer of clinkers or potsherds; but, as the furnace attains its maximum heat, sufficient clinkers are formed to serve the purpose. All round the grate-room a bank, A, is raised, termed the *siege*, on which the pots are placed, so that the fire lies, as it were, below the bottom of the pots, and in the centre of the furnace. The sides of the furnace are a little higher than the top of the pots, and the arch or crown is made as low as possible to be consistent with durability.

Fig. 138 is an exterior view of the brick dome, and Fig. 139 an interior sectional elevation of the same,

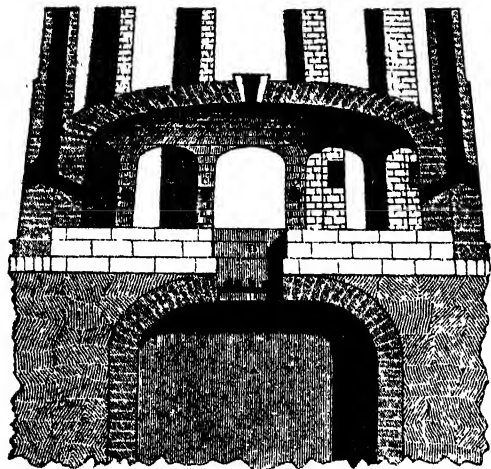
Fig. 138.



showing the position of the flues, arches, and cave. In Fig. 138, the letters A A indicate the sole of the furnace; B B, the flues; C C, openings or arches, which, after intro-

ducing the pots, are built up, leaving only working holes; D is the door for introducing the fuel; and E the roof or dome. In Fig. 139, A is the cave or air-tunnel below the furnace; B, pit of furnace, with grates below;

Fig. 139.



C C, flue or linnet noles, through which the flame, not being allowed to issue from the centre, passes up the flues, discharging into the brick dome, and from thence into the funnel and chimney shaft.

The dimensions of a convenient flint-glass melting furnace are given by Mr. APSLEY PELLATT as follows:—A furnace for ten pots of thirty-six inches diameter is twelve feet seven inches in interior diameter, including the flues; the height to the inside of the dome is four and a half feet; each of the arches is three feet one inch by three feet three and a half inches to the highest part. The fire is regulated by the stoker or *teaser*—from the French, *tiseur*—who can raise the heat of the furnace to the highest pitch by opening holes at the bottom of the grate. A ten-pot furnace consumes from eighteen to twenty-four tons of coal per week.

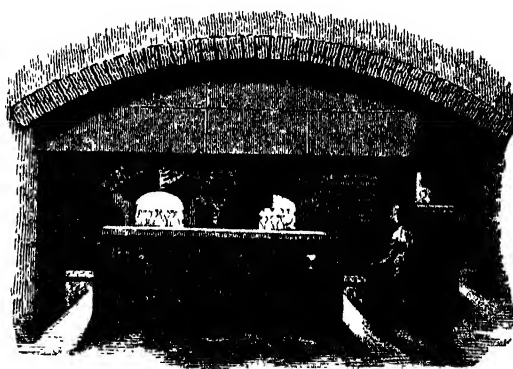
RICHARDSON and RONALDS remark, that the construction of the melting-furnaces in a glass-house is attended with many difficulties, against which it is almost impossible to provide; and the wear and tear becomes a serious item to the manufacturer. The prevailing temperature of a glass furnace, about 20·000° Fahr., presents in itself a serious difficulty; but in cases where open pots are employed, this is materially increased by the volatility of the alkalies, which amounts to nearly twenty-five per cent. of the potassa. The binary compound of silicic acid and alumina becomes changed into a ternary one, through the action of the alkali when clay is employed, and into a silicate of potassa or soda where freestone is substituted; in each case a fusible compound results, which rapidly wastes away, and at last, both pots and furnaces become too much corroded for use. In ordinary cases, three years is the usual duration of these furnaces, except in flint-glass-houses, where they last longer, from the lower melting point of the materials, and the peculiar shape of the pots.

The sides of the furnace are constructed of bricks, formed in moulds made for the purpose. The best fire-clay, mixed with the remains of old pots coarsely ground, is the material employed for making these bricks; but these clays would be much improved for this and many other purposes, by the addition of some coarse sand, or ground pure sandstones. The roof is generally made of sandstone alone, of a coarse grit, and very porous. No cement is employed in the arch, the expansion of the stone, and the partial fusing of the interior surfaces afterwards, bind the whole sufficiently well together.

The crown and plate-glass furnaces are similar to the flint; they are placed also in the middle of the cone, but contain only from four to six pots, each of the capacity of half a ton of metal.

Besides the main or melting furnace, a glass-house contains a variety of furnaces and arches adjoining or around the inside of the cone, for different subsidiary operations. The *calcar arch*, for burning frit, now little used, is a common reverberatory furnace, about ten feet long, seven feet wide, and two in height. In crown-glass works there are also the *blowing furnace*, the *bottoming hole*, and the *flashing furnace*, besides an aperture in the latter termed the *nose-hole*. The uses of these will be explained in connection with the crown-glass manufacture. Lastly, the *leer* or annealing oven is one of the most important appendages of every glass-house. This is the name given to a low arch, open at both ends, in which the manufactured goods are allowed to cool gradually. The arch is usually about sixty feet in length, five feet wide, and not more than from one to two in height. Adjoining the door or receiving end is a small furnace on each side, by which the temperature at that end is maintained just short of a melting heat; but, as there is no other heating power, the arch or oven experiences less and less of the heat as the distance from the mouth is greater,

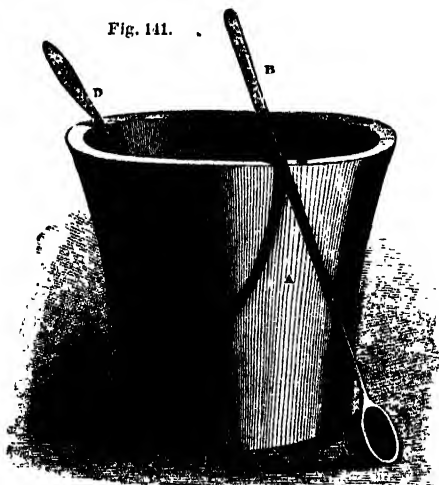
Fig. 140.



until, at the remote or discharging extremity, the temperature is scarcely higher than that of the atmosphere. There are usually from two to four of these annealing arches placed side by side, as represented in the above engraving, Fig. 140. Along the floor of each is a miniature railway, upon which two rows of iron

trays, called *leer pans*, travel from the hot to the cooler end, where they are taken out. The pans are moved slowly along the leer by means of an endless chain, or sometimes they are gradually pushed forward by the trays last put in. The fuel employed is coke, which imparts the most regular heat for annealing, and is the freest from smoke, the carbon of which, when coal is used, injures the color of the glass. The time required for proper annealing varies from six to sixty hours, the weighty articles requiring the most heat and time. The hotter the goods enter the arch the better, and on this account large articles, before being introduced, receive a final re-heating at the mouth of an empty pot, heated by beechwood, and called the *glory-hole*. Much of the success of annealing depends on the proper direction of the wind, which ought to pass over the fuel of the leer toward the leer chimney at the cooler end, so that the hot air may always radiate in the downward current upon the goods. When an upward or contrary current of wind drives back the heated air from the cool or chimney end toward the fuel at the upper end, where it comes into contact with the hot articles just introduced, great losses from breakage often occur.

Fig. 141.



Kilns, which differ from leers in being closed at the further end, were formerly in general use for annealing goods intended for deep cutting, the kilns, when filled,

being carefully closed up along with the burning fuel. The time required for cooling in this case was usually about a week. To avoid so much delay, the kilns have been superseded by the use of iron covers or a bedding of sand in leers; also by lengthening the leer fire-places, and not filling the pans with glass too quickly.

THE POTS.—The crucibles, or pots, in which the vitreous mixture is melted, require every care to be taken in their preparation. Those used for bottle, crown, and plate-glass have the form of a truncated cone, A—Fig. 141—the narrow end being the base. Their depth is usually four feet six inches; their diameter at top, from four feet to four feet six inches, and at the bottom, about three feet four or six inches. In the same figure are shown the ladle, B, for taking out the glass, and the stirring rod, D. The pots for flint-glass are hooded or covered at the top, and have a mouth, B, in front like a muffle, as shown in Fig. 142; but those for crown, plate, and bottle-glass are open. The horse-shoe-shaped piece of fire-clay, *a*, is inserted in the mouth during the melting, to diminish the aperture.

Fig. 142.



Fine clay is the material of which the glass-pots are made, and it must be as pure and refractory as can be obtained, free from every trace of lime in any state, and sulphide of iron; and the less oxide of iron the better. The kind of slate clay dug out of the coal formation near Stourbridge, which contains very little, if anything, besides silicic acid and alumina, is decidedly preferred to all other compounds found in this country. The clay is mixed with varying proportions of the remains of the old pots, and the *tempering*, or previous preparation of the mixture, requires great attention. A certain quantity of the ground materials, after being mixed with water, is stored away in large wooden bins or receptacles, and turned over from time to time, during which a workman treads it under his naked feet. This *kneading* of the clay renders it very uniform and free from particles of air. The following is the composition of some of the clays employed:—

	Stourbridge Richardson.				Stourbridge Editor				Rhuabon.		
Silicic acid,.....	68.05	63.70	64.10	.....	63.99	.....	61.77	.....	63.99	.....	61.77
Alumina,.....	18.85	20.70	23.15	.....	20.84	.....	18.97	.....	20.84	.....	18.97
Lime,.....	80	1.30	.....	.....	30	.....	1.53	.....	30	.....	1.53
Magnesia,.....	.....	.....	90	.....	94	.....	91	.....	94	.....	91
Iron,.....	5.10	1.00	1.85	.....	75	.....	17	.....	75	.....	17
Water,.....	6.00	10.30	10.00	.....	11.67	.....	14.79	.....	11.67	.....	14.79
Loss,.....	1.20	3.00	.....	.....	1.51	.....	1.86	.....	1.51	.....	1.86

The proportions given by BARRUEL as most suitable for glass-pots of any description, are thirteen parts of crude aluminous clay, twelve parts of calcined silicious clay, and three parts of the remains of old pots. The last-mentioned material assists the more regular drying of the pots, and renders the whole body more porous, and less liable to crack by heat.

When the mass has been kneaded three times over until it acquires a pasty consistence, it is rolled into small pieces about the size of a sausage, and these wet rolls are placed together upon a wooden or leaden slab, to the thickness of four inches, to form the bottom. It is then turned up at the edges, and built, layer above layer, in successive rings, all formed by the eye of the

workman, without the use of a mould. When the pot has been finished, the sides are made smooth by means of small wooden scrapers.

After the glass pot is formed, it is allowed to remain for a considerable time in an apartment heated by a flue to a little above the ordinary temperature—about 80°—in order that it may be slowly dried in an equal manner throughout its whole thickness. Two or three years is the time allowed by some manufacturers for this gradual desiccation.

Before the pot is set in the furnace, it must be subjected to an annealing process, which consists in gradually increasing its temperature during several days to bright redness. This is usually done in a reverberatory constructed for the purpose, the fire in which must be raised very slowly, not more than a shovelful of coals being introduced at a time, and that at regular intervals. While at a bright red or even a white heat, the pot is quickly transferred, with the assistance of adequate machinery, into its seat in the hot furnace; a part of the face of which must be pulled down, to allow of the ready extraction of the old pot, and introduction of the new one. Before the pot is used, it is *glazed*, as it is technically termed, before being filled with materials; that is, some cullet or old glass is thrown into it, and spread over the sides in a molten state. This penetrates to the depth of a few lines into the substance of the pot, and forms a hard, difficultly fusible enamel, which protects the pot from the further action of the substances added.

The setting of a new pot is a very arduous undertaking, and is generally attended with great excitement, and even danger, on account of the intense heat to which the workmen are exposed. It is generally performed at the end of the week when the work of the glass-house is slackened, and all hands are required to be present to assist at the operation.

A good pot-maker, says Mr. HENRY CHANCE, with two assistants, can furnish three or four pots per week. After a careful drying of many months, they are made ready for the furnace, as has been stated, by a previous heating in a kiln or pot-arch. Here a small lump of coal, thrown against its side, tests the soundness of the pot. If, when struck, it rings well, its future is promising; but if it returns a dull sound, it will probably be short-lived in the furnace, though now and then such a pot will disappoint the bad opinions formed of it, and turn out a respectable pot after all.

The terrible task of setting these pots in the furnace, continues Mr. CHANCE, falls upon the glass-house crew, and the nicety with which these enormous vessels are adjusted in their place, in the teeth of a consuming fire, is, perhaps, that operation which, in the many marvels of glass-making, would most astonish a stranger to such scenes. The average duration of the pots, when thus fixed, is about seven weeks. Some attain the age of ten or twelve; while others, as every manufacturer well knows, terminate their existence prematurely, either from the naturally defective constitution of the pot, or from bad treatment in the pot-arch, or more frequently from its having been *starved*—that is, exposed to a current of cold air in the furnace, through the neglect of the attendant. The breakage of a pot often disturbs

the furnace to such an extent, that the breakage of others frequently follows, and many weeks will sometimes elapse before the disorganization thus produced can be rectified. The loss of the pot and the contained *metal* is nothing as compared with the injury which the glass in the surviving pots, and these pots themselves, are apt to sustain.

CRUDE MATERIALS FOR GLASS-MAKING.—The chemical or theoretical composition of the different varieties of glass has been already given at pages 191 and 192; but as it is quite impossible to obtain or prepare the ingredients in a state of chemical purity previous to fusing them together, it will be necessary to explain the sources from which the materials that go to constitute the different glasses are practically derived for the purposes of the manufacture.

Silica.—It has been stated that all true glasses are practically composed of silica, or silicic acid, in combination with at least two alkaline or earthy bases, and sometimes oxides of lead, zinc, and other metals. Silica, silicic acid, or tetroxide of silicium— SiO_2 —is the principal ingredient. It is very abundant in nature, forming a principal constituent in rocks and stones, and existing in a free and almost pure state in flint, agate, chalcedony, rock-crystal, and quartz, the last two being its purest form. Formerly, flint—*silx*—calcined and ground, was used as the source of the silica, and hence the name of *flint-glass*. Sand, however, is now employed as the most general and economical source of silica, and renders the process of grinding unnecessary. At the same time the great variations in the purity of this material render requisite a careful selection for the different kinds of glass, and the manufacturer must choose such as the microscope and analysis show to be most suitable for his purpose. The finest English sands are from Alum Bay in the Isle of Wight, and Lynn on the coast of Norfolk. The French obtain a very superior sand from the forest of Fontainebleau, in the neighborhood of Paris; and Mr. H. CHANCE justly remarks, that to the purity of this and their other materials the superior color of their glass may be partly ascribed.

The sand, being always more or less impure when brought to the glass-works, is conveyed to an upper room, and thrown into a trough of water, where it is carefully washed. It is then placed in a trough over an oven, and, when partially dried, passes through holes into the oven. When quite dry, it leaves the oven in the state of fine, glittering white particles, like powdered quartz. These precautions are not necessary for bottle-glass.

Potassa and Soda.—The alkalis used in the manufacture of common colored glass, such as those used for green bottles, are obtained, as far as the potassa is concerned, from common *ashes*, and the soda from the *ashes of sea-plants*, or refuse soda. Better kinds of glass are made with crude potassa and soda-ash, and the best from purified potassa and soda-ash. Not more than thirty years have elapsed since crown and sheet glass were manufactured from the crude alkali obtained from kelp, the preparation of which for this purpose employed a large population on the Northern shores of Scotland and West of Ireland, and the abandonment of this material, when the duty was taken off barilla,

plunged whole districts into idleness and misery. The kelp was used simply in combination with sand—the kelp containing soda and potassa, and furnishing the necessary amount of lime; but the glass thus produced was of very variable, and often most inferior quality. The discovery of LE BLANC in 1792, which effected the conversion of common salt into carbonate of soda, was the commencement of a new era in the history of Continental flint-glass; but the introduction of carbonate of soda, prepared from salt, into the glass manufacture of England, dates only from the year 1831. Ultimately sulphate of soda was substituted, except for plate-glass, the manufacturers of which still adhere to the carbonate. The black bottles of Newcastle are made from common rock-salt, and sand from the bed of the river, with the carbonate of lime of the soap-works, and the tank waste of the alkali makers; but for all better kinds of glass the circuitous combination of silica and alkali is still found necessary. The carbonate of potassa is obtained chiefly from Canada and the United States, and requires a process of washing previous to use. The state to which it is brought by the process of cleansing is that of fine white grains, differing but little, to an unpractised eye, from the prepared sand.

Lime.—This substance, which forms an important constituent in flint-glass, may be introduced either as a carbonate, or slaked or burned. Limestone, however, that contains proto-carbonate of iron, must be excluded from the mixture for making white glass. The action of lime is to render the alkaline silicates insoluble, and when rightly balanced by the other ingredients, it promotes the fusion of the whole, and improves the quality, but when added in excess, the glass becomes hard and difficult to work, and subject to devitrification.

Lead.—The next substance in point of importance is lead, which forms the distinguishing ingredient in crystal or common flint-glass, optical glass, and strass. These glasses are fused from a mixture containing litharge— PbO —or minium—red lead, Pb_3O_4 . Of these two compounds, the latter is preferred on account of its finer state of division, its pulverulent form, and because it is decomposed in the glass-pot into ordinary protoxide of lead and oxygen, which latter oxidizes, and removes many impurities, as, for example, charcoal. An excess of lead acts injuriously upon the melting vessels, and, besides inducing too great softness in the glass, gives it a yellow tinge.

Baryta.—This substance, in the form known as *heavy spar*— BaO, SO_3 —is sometimes added to the constituents of common bottle-glass, to render it more easy of fusion.

Alumina.—The sesquioxide of aluminum— Al_2O_3 —though seldom purposely introduced into glass, is always accidentally present, brought there by the action of the materials upon the clay of the pots in which they are melted. Alumina, if present in any quantity, is always an undesirable ingredient, as, by increasing the number of silicates, it renders the glass more liable to devitrification, it being well known that the more compound a glass is, the more does it display this tendency. Hence, bottle-glass, which contains a greater variety of bases than any other, is of all the most easily devitrified.

Iron.—Another unwelcome element is iron, which is

almost always present in the sand, in the sulphate of soda, when employed, and in the chalk, partly in the state of protoxide, the coloring effect of which is partially destroyed by other ingredients, to be afterwards mentioned.

Arsenic.—A little arsenic promotes the decomposition of the other ingredients, and tends to dissipate carbonaceous impurities not otherwise disposed of; but, in excess, it produces a milkiness in the glass, which time will increase.

Cullet.—Another substance is added—abundantly produced in every manufactory of glass—namely, a quantity of waste glass, or cullet, which, being more fusible than the raw materials, facilitates the melting. For this purpose, the waste glass in the glass-house, and that collected in the neighborhood, are carefully sorted, cleaned, ground, and incorporated with the mixture for similar kinds of glass. Great care must, however, be taken that no broken glass of an inferior kind is mixed with the ingredients for finer glass. The cullet not only incites fusion, but materially aids the union of the bases with the silicic acid.

Decoloring Materials.—It has been stated in the historical notice that every description of glass exhibits a tendency to color, which probably led to the idea of stained glass. This tendency is more or less developed, even when proper proportions and the purest materials for the mixture have been employed; and as any tinge is considered a defect in white glass, or that which is employed for windows and particularly in the finer kinds of glass, certain materials are employed with the special object of counteracting it. To this class of substances belong *binocide of manganese*, *arsenic*, already mentioned, and *nitrate of potassa*. The accidental elements which usually color the glass are *iron* and *carbon*, or carbonaceous matters, and in all cases the substances above-mentioned are employed to neutralize or counteract these by means of *oxidation*.

For example, if particles of carbon or soot from the fire or flame become mixed and surrounded with the melted glass, these, by their exclusion from the access of air, are prevented burning, and a brown or nearly black color is produced, which is removed by the conversion of the carbon into carbonic oxide through the influence of the oxidizing or decoloring material. The manner in which manganese acts on the protoxide of iron has been already explained—page 189—and is similar to its action on carbonaceous matters, which are thus removed in a gaseous form from the melted mass. A few ounces of the binocide of manganese are, therefore, usually added to the materials for making flint-glass, which is always required in a state of great purity; and, from the cleansing action of this material, it has received the familiar title of *glass-makers' soap*. It must, however, be used sparingly; for an excess of it produces a compound of silicic acid with sesquioxide of manganese, which communicates a lilac or amethystine color to the glass. The approved remedy for this, when the error has been committed, is to stir up the colored mass with a wooden pole, which reduces the sesquioxide to the protoxide, and the lilac color disappears.

Some manufacturers use manganese, on account of the reddish tinge it imparts to glass, expressly to disguise the bad green or yellow color produced by the other materials. In this case two tinged glasses are formed, which mask each other's defects, the green and red rays combining together, as supplementary colors, to transmit white light. Indeed, in plate-glass for fine windows, a slight excess of manganese is sometimes allowed, expressly to produce a delicate amethystine tint, which improves the complexion of persons who receive the light of day through the window.

Smalt, a blue glass, is sometimes used, like manganese, to mask the bad color produced by the other materials. Properly speaking, however, the decoloring agents are those which act by oxidizing the carbon or the protoxide of iron, and thereby actually expelling the lime. In this way nitrate of potassa reacts before the glass enters into perfect fusion; arsenious acid, arsenic acid, and their salts, exert their action at a temperature above the fusing point, and are volatilized.

Glass from Felspar.—The making of glass by means of felspar is an idea which naturally suggests itself to the mind, when one considers the ready vitrification of this mineral, and was suggested even long ago by M. GHÉRAND in the memoirs of the Academy of Berlin. According to this authority, the following mixture is proper for a window-glass, namely, two parts felspar, two parts sand, one part chalk, which would give, for the composition of the glass, supposing no volatilization of the potassa during the melting, nearly the following:—

	Centesimally.
Silica,	73
Alumina,	8
Potassa,	7
Lime,	12
	100

These ill-calculated proportions could only give a glass difficult to melt, and prone to devitrify. This, says DUMAS, is exactly what happened in an experiment made on the large scale by M. REY, under the eyes of CHAPTAL and ALLUT. The melting required a twice longer time than the usual, but it furnished a beautiful glass. The experiment was supposed to be a fortunate one; but when the crucible was cooled sufficiently to admit of the working of the mass, it was found quite opaque, milky, and clotty—in fact, devitrified. Must felspar, therefore, be renounced? It is difficult to admit this. If a mixture be made of one hundred parts of felspar, one hundred parts of Arcueil clay, or some analogous clay, and eighty of quicklime, or its equivalent in chalk, a glass of the following composition will be produced:—

	Felspar.	Clay.	Glass	Or centesimally.
Silica,	66	63	129	46.3
Alumina,	18	37	55	20.0
Potassa,	16	—	16	5.7
Lime,	—	—	80	28.0
			280	100.0

—that is to say, a glass which, if the clay is free from iron, would be quite of the same nature and color as bottle-glass, and which would present advantages as well as disadvantages. As regards common window-

glass, or analogous glasses, felspar should be capable of entering into these in the proportion of one-third or one-fourth, without serious disadvantage. A glass would be produced which would differ from common glass only by the presence of four hundredths of alumina, and glasses are met with in commerce which contain this quantity and even more. Lastly, it is probable that by suitable additions of borax, boracic acid, or oxide of lead, one might get felspar itself to produce a glass endowed with all the desirable qualities.

Glass from Volcanic Products.—DUMAS remarks that certain lavas, pumices, pitchstone, and other volcanic products, approach so closely to bottle-glass in their composition, that the possibility of turning them to account in this way cannot be doubted. The merit of the first attempts of this kind is due to CHAPTAL; and if these attempts did not succeed, this must be attributed to the time at which they were made, rather than to the idea itself, which is both good in theory and must be capable of succeeding in practice. The analyses will be sufficient to prove this:—

	Lipart pumice.	Basalt of Hasenburgh	Basalt of Staffa.	Pitchstone of Minni.
Silica,	77.5	44.5	48.0	73.0
Alumina,	17.5	16.7	16.0	14.5
Oxide of iron, ...	1.7	20.0	16.0	1.0
Soda, }	3.0	2.6	4.0	1.75
Potassa, }				
Lime,	—	9.5	9.0	1.0
Magnesia,	—	2.2	—	—
Water,	—	2.0	5.0	8.5
Hydrochloric acid, ..	—	—	1.0	.25
Loss, .....	.30	2.5	1.0	.25
	100.0	100.0	100.0	100.0

With pumice-stone, forge-scoria, chalk, and a little soda in proper proportions, bottle-glass might therefore be made. Basalt would require only the addition of a little chalk and soda. Pitchstone treated like pumice-stone would furnish it also.

The trials made by the directions of CHAPTAL succeeded so far as the matter examined by him was employed; but when another volcanic product came to be used, the results were bad, the proportions being deranged. A very simple analysis would have prevented all trouble, and would have preserved their proper rank to these volcanic matters, the excellent effects of which have been demonstrated by a sufficiently long experience.

It was in 1780 that CHAPTAL, then Professor of Chemistry at Montpellier, proposed the use of lava. M. DUCROS, a glassmaker in the environs of Alais, melted, with coal, the lava of the extinct volcano of Montferrier, without any addition, and made some bottles of it. M. de CASTLEVIEL, another glassmaker of the country, melted, with wood fuel, a mixture of sand, lava, and soda, and thus produced bottles lighter and stronger than those usually manufactured. These bottles had such great success that the demand could not be supplied. But at the expiration of four years, the bottles which were produced no longer resembled the first ones: they were much inferior; the manufactory lost its reputation, and was compelled to abandon the system which it had just tried with so much success.

The nature of the lava, therefore, had changed, and

the same proportions being no longer suitable, an analysis alone could have guided the operator. It is with this that the process must be commenced, if it is intended to resume a manufacture, worthy, in so many respects, of being submitted to trials which the state of science would now render much easier. It was in consequence of taking a different course that M. de CASTLEVIEL failed, and that M. FOUGEROUX de BONDAROY, who appears to have been occupied in 1787 with the same subject, without any knowledge of the preceding facts, succeeded no better.

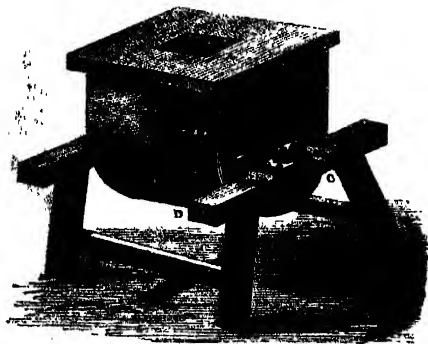
THE FUEL.—The fuel formerly employed in England in the making of glass was exclusively *coal*, but of late it has been found that, in London especially, many advantages result from using *oven-burned coke*, which produces less smoke and soot, and is, therefore, much better adapted for the finer glasses. Some glass-houses have all the requisite accommodation for making coke. In France both coal and coke are employed, and sometimes *wood*; but BARRUEL states that wood has been generally abandoned as being more costly, and producing less heat than coal, so that with the former the fusing and refining of the metal require longer time. In Germany *wood* is generally employed, and in some few places *peat*. Even the best air-dried wood would fall far short of producing the desired effect, in consequence of the amount of water which it still retains, and therefore it has been the practice on the Continent, from a very ancient period, to bake the air-dried wood in a particular kind of furnace until it begins to become brown, or until the whole of its water has been volatilized. Peat when used in the glass-house must be perfectly dry, and afford only a small amount of ash.

PREPARATION OF THE MATERIALS.—A great saving of time and fuel is effected by carefully grinding and intimately mixing the materials previous to the melting. For this purpose edgo-stones and coarse sieves are essential in a glass-house. Until quite recently, the mixing and sifting were always performed by hand, and the operation was therefore imperfectly performed, the mixture so produced being little calculated to favor those chemical changes and mutual reactions of the materials which are necessary to the formation of a

partly in section in Fig. 143, is made entirely of wood, and consists of a semi-cylindrical chamber, with an opening, A, at the top, for introducing the materials, and another in the semicircular bottom at D, through which they are removed; B is a cylinder in which a number of oblique beaters are fixed, and the whole is made to revolve by a handle or by a shaft from the steam-engine connected with the axis, C. Mr. COOPER applied with the best effect a simple revolving wooden barrel, similar to those employed in the powder factories. The composition, when mixed, is termed *batch* or *frit*—the latter word being derived from the circumstance, that during the period when barilla, kelp, and other forms of crude alkali were in use, it was the custom to subject the materials to the preliminary operation of *fritting* or stirring them together under the heat of a reverberatory furnace, thereby effecting *partial decomposition*, and burning off any carbonaceous impurities; but the introduction of alkali prepared from common salt has, in most cases, removed the necessity of this treatment. One great advantage of fritting consisted in the partial union which it effected between the silicic acid and the bases, so that the latter were not volatilized in the furnace previous to the formation of the glass, and the pots and sides of the furnace were consequently less exposed to the injurious action of their vapors. With the purer materials now employed in the manufacture, the advantages gained by the operation are not generally considered sufficient to compensate for the loss of fuel incurred in producing the high degree of heat required to perform it.

MELTING.—The raw materials, consisting essentially of sand or silica as the base, and alkali as the flux or solvent, having been thoroughly incorporated with a suitable proportion of cullet or broken glass of the same kind, are introduced by means of a clean iron shovel into the melting-pot, which has been previously raised to a white heat. But the whole of the mixture is not introduced at once, for the mass of glass which a pot will hold occupies before fusion, in the state of frit, just twice the space of the melted glass. Not more than one-third of the mixture is therefore introduced at first through the working holes, the temperature is then raised to the maximum, and as the mass subsides by melting, a fresh quantity is introduced, until the pot is filled with melted glass. During the whole period of the melting or *fouling*, the stokers or *teazers* keep the furnace well supplied with fuel, so as to prevent any portion of the grates becoming uncovered, in which case a rush of cold air from below might split some of the pots. At the same time the *founders*—from the French, *fondeurs*—are engaged in noting the progress of the fusion, by taking from time to time proofs or drops from the pots, by means of a short rod, flattened at one end, and examining if any undissolved grains of sand are perceptible on refrigeration, and whether the mass, which still contains a quantity of air-bubbles, appears uniform throughout. So long as carbonic acid is evolved in abundance, or during the *boil*, the mass is agitated by the escape of the larger bubbles of gas in a manner most favorable to the operation, this motion answers the

Fig. 143.



homogeneous fluid transparent body. To obviate this disadvantage, a mixing apparatus, especially intended for crown-glass, has lately been contrived by Mr. CHANCE. This very simple machine, which is shown

purpose of stirring, and mixes the compounds of variable degrees of fusibility and density, which are at first produced, with each other; at a later period, when the disengagement of gas ceases, the denser compounds are apt to settle down at the bottom of the pot, where the temperature is about one-fourth lower, and is, consequently, incapable of preventing the deposition by the production of ascending currents. This evil is moderated on the Continent by stirring with the scooping ladle, or by thrusting a piece of arsenious acid to the bottom of the pot, and thus causing a forcible expulsion of vapor from that part of the vessel. At the close of the melting process, the contents of the pot are not by any means pure, or equally mixed. All the solid matter is dissolved, but the mass of glass is full of small vesicles of gas, presents a spongy rather than a dense appearance, and is not yet in a state fit for working. The surface is also covered by a layer of so-called *glass-gall* or *sandiver*, a melted mixture of salts, which have not been volatilized, nor combined with silica during the process of melting, and consisting chiefly of chloride of potassium—or sodium—and sulphates, which in consequence of imperfect vitrification have escaped decomposition.—*Knapp*.

The following, says RICHARDSON and RONALDS, has been found to be the composition of this saline matter, glass-gall or sandiver, which is skimmed off the surface of the melting materials, and is technically termed *salts*:—

Constituents.	German plate glass.	Crystal- glass.	Bottle- glass.
Water,	1.65	.10	1.00
Sulphate of soda,	83.32	90.51	55.92
Sulphate of lime,	10.35	6.00	25.11
Chloride of sodium,	1.43	.04	.20
Carbonate of soda,	trace	—	—
Potassa,	—	—	trace
Insoluble matter,	3.25	3.35	17.77
	100.00	100.00	100.00

Glass-gall, when occurring in large quantity, is removed with ladles, and is employed on the Continent by saltpetre and alum manufacturers, or workers in bronze; in the varieties of glass prepared from pure or purified materials, where, instead of crude potassa, ashes, or soda, purified substances have been employed, either no glass-gall is produced, or that which appears is easily removed by volatilization.

FINING.—For some time the glass does not become transparent, the opacity being due to bubbles of air or gas, and to the lime and earthy impurities which do not fuse. The object of the *fining*, which is the last process in glass-making, properly so called, is the removal of these by the subsidence of the heavier particles to the bottom and the escape of gas at the surface. For this purpose the glass must be brought to the most fluid state possible, and the heat is therefore raised and sustained for some hours at the highest point. In Germany this part of the process is termed *heiss-schüren*, or *hot-covering*. In forty or forty-eight hours after charging, the vitrification is complete. When all the gas-bubbles have passed off, and the sandiver has become transparent and colorless, the temperature of the pot is lowered by diminishing the draught—a process termed *kalt-schüren*, or *cold-covering*—the object of which is to

bring the glass from a state of nearly perfect fluidity, in which it could not be worked, to that free viscid or plastic condition necessary for the working. For this purpose the bars of the furnace are plastered up. The great thickness of the walls, and the slow combustion of the fuel, which is supplied in moderate quantity, keep the furnace hot enough to retain the glass in a workable viscid state during the period in which the glass is blown or otherwise shaped into the required forms.

The reactions which take place in the pot or crucible are very easy to understand. For example, if the silica has been mixed with carbonate of soda and carbonate of lime, the silica, at a high temperature, seizes on the soda and lime, and the carbonic acid is disengaged. In the same manner, if silica has been mixed with carbonate of potassa and minium, this last returns to the state of massicot, and the silica then combines with it and the potassa. There is, therefore, in this case, first a disengagement of oxygen, then an elimination of carbonic acid.

These evolutions of gas which constantly accompany the production of glass, explain the presence of the *air bubbles* already mentioned as so frequently observed in the vitreous mass. To expel these, it has been stated that the temperature must be raised very high, that the glass may become quite fluid. But as the potassa and soda may be volatilized at this high degree of heat, one is obliged to introduce into the compositions much more potassa and soda than the glass is intended to retain.

This elevated temperature is also necessary in all cases where impure alkalis are used. The presence of the chlorides, and even that of the sulphates which melt without mixing with the glass, would occasion in the latter a multitude of white and opaque nodules disseminated through its mass. At a high heat both of these matters, being lighter than the glass, rise and float on the surface, constituting the principal portions of the glass-gall or sandiver above alluded to. It must be stated, however, that ever since the salts of soda have been sold at a low price, and are consequently generally used, very little glass-gall has been produced in the manufacture of the ordinary kinds of white glass; but in bottle-works this impurity always occurs, because crude sodas are employed.

FAULTS IN THE GLASS.—Notwithstanding all the precautions that may be taken, air-bubbles frequently remain, and generally exist in great number when the fining process has been obstructed by too great difficulty of fusion in the glass. They are technically termed *seed*, *blibe*, or *blister*.

Two further accidents to which the glass is liable are known as *threads* or *strings*, which are generally contracted during the blowing, when cold particles of glass drop into the viscid or imperfectly melted metal, and not having time to undergo fusion remain hard, and appear as unsightly projections from the blown vessels.

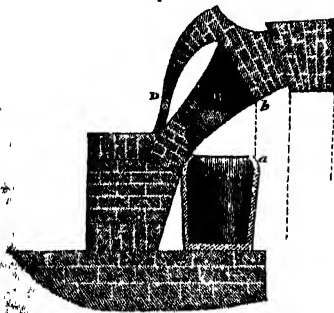
Waves and *striae* are faults of too common occurrence, arising from a want of homogeneity in the vitreous mass. The latter of these terms is applied to the effect produced when the density of the glass, in consequence of imperfect fusion, is not uniform throughout.

and all the parts, though equal in transparency, do not refract the light equally; and consequently, images of objects seen through the glass appear out of place or distorted. This fault is very objectionable in plate-glass for mirrors or windows, as well as in crystal or flint-glass for optical purposes. *Waves* are superficial and protuberant striæ, which always occur when the glass is blown too cold.

A not less serious evil, which is frequently a source of color in the glass, arises from the action of the alkaline vapors upon the constituents of the sides or roof of the furnace, particularly when chloride of sodium or sulphate of soda is used in the manufacture. The volatilization of the alkali, whether soda or potassa, produces over the pots a rapid vitrification of the bricks of the vault, and hence drops of *colored glass*, known by the name of *tears*, which occasionally fall into the pots. These are produced by the silicic acid of the bricks combining with the alkali, and forming with it, and with the iron and alumina of the clay, a green and very infusible glass, which sinks to the bottom of the pot from its greater density, leaving in its course a fibrous tail which remains in the glass. Imperfections of the same kind are produced, though less frequently, by the action of the glass upon the walls of the pot itself.

According to KIRN, the drops of aluminous glass may be prevented from falling into the pots by constructing the latter and the arch of the furnace in the manner represented in Fig. 144. In this case the portion of the wall of the furnace, which comprises the working hole, *B*, is made so large that drops, falling perpendicularly from any protuberance or irregularity, *b*, can only reach the

Fig. 144.



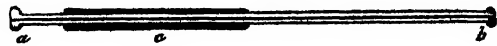
exterior of the inflected margin, *a*, of the pot, *A*; and the size of the working hole is reduced to the proper dimensions by a second less solid arch, *D*. Another plan, mentioned by KNAPP, is to make the working hole in the perpendicular wall of the furnace, and to spring the arch of such a form that the angle of the part over the pot may be sufficient to cause the *tears* to flow down the arch instead of dropping into the pot.

WORKING TOOLS AND APPARATUS.—The tools represented by BLANCOURT, in his work *On the Art of Glass*, which was printed at London in 1699, are almost precisely the same as those now in use; and the author's account of their mode of working might almost be taken as a description of the modern process. To these

curious on the subject, BLANCOURT's description is well worthy of perusal.

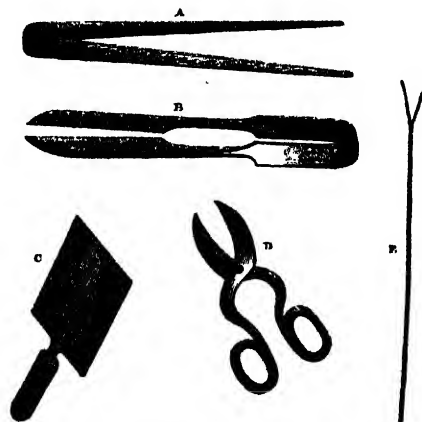
The most important of these instruments is the *pipe*, on the end of which the glass is taken up by the workman, and blown into spheres or bulbs, to be subsequently shaped into different forms, as will be afterwards described. A section of this indispensable instrument is shown in Fig. 145. It is simply a tube,

Fig. 145.



composed of wrought-iron, four to five feet long, one inch thick, and about one quarter to one inch in the bore. It is provided with a knob at each end, the one of which, *a*, serves as a mouth-piece, whilst to the other, *b*, the melted glass is attached. The upper portion is surrounded by a wooden cover, *c*, to protect the hands of the workman from the heat of the metal. A companion to this instrument is a solid iron rod, known as the *pontil* or *ponty*, which serves to receive the glass after it is blown on the pipe. The *spring-tool*, *A*—Fig. 146

Fig. 146.



—is a species of tongs for laying hold of half-formed handles, and for seizing the glass while making. The *pucellas*, *B*, have prongs resembling the cutting part of shears, but blunt, and are used for rubbing the outside of solid or hollow glass, and pressing it into smaller diameter, at the same time elongating the parts by rotation. The battledore, *C*, is made of wood, and is used for flattening the glass when necessary. The shears, *D*, are strong scissors for cutting and shaping the edges and handles of glass vessels while in a soft state. The fork, *E*, is employed for carrying the finished articles to the annealing oven.

An important part of the glass-blower's furniture is the *marver*, which consists of an iron plate or slab, resting on a stone or on wooden supports, and having a polished surface, on which the mass of glass that has been gathered at the end of the blowing tube is rolled, to give it a symmetrical form. The term *marver* is derived from the French *marbre*, a marble slab being formerly used. The *glass-maker's chair*—Fig. 147—is a flat seat of wood, about ten inches wide, each end of which is fixed to a frame connected with four legs and two

inclined arms, upon which is screwed an edging of wrought-iron for rolling the blowing tube with the hot

FIG. 147.



glass backwards and forwards with the left hand, while the required form is given to the glass with the pucellas held in the right.

Continual rotation of the molted mass is the principal point to be attended to in most of the glass-blower's operations; but these will be best described in connection with the special manufacture of the different varieties of glass.

SPECIAL MANUFACTURE.—A visit to the glass-house will convey a much more vivid idea of the beautiful art of the glass-blower, and the wonderful material with which he works, than the most elaborate written description or pictorial illustrations. There is, moreover, so much of the *mechanical* connected with the fabrication of glass, that great part of it does not properly fall within the scope of this work. In proceeding, therefore, to describe the details of the different departments of the manufacture, the Editor will dwell as briefly as possible on those operations which do not involve the application of chemical agencies.

The arrangement to be followed will be somewhat similar to that already indicated, as adopted by KNAPP, but with some important modifications—beginning with the coarser or commoner qualities, and rising by a natural gradation to the finer and rarer kinds of glass manufactured for optical lenses or ornamental purposes. On this principle, the following arrangement will embrace all that is necessary:—I. ORDINARY or GREEN BOTTLE-GLASS. II. WHITE BOTTLE-GLASS, including *refractory Bohemian and Foreign crown*. III. WINDOW-GLASS, embracing—1. *English crown*, and 2. *Sheet or cylinder glass*. IV. PLATE-GLASS, with the process of silvering mirrors. V. CRYSTAL or COMMON FLINT-GLASS, and OPTICAL FLINT-GLASS. VI. STRASS and COLORED or STAINED GLASS. VII. SOLUBLE GLASS.

I. GREEN BOTTLE-GLASS.—The materials for common glass bottles are coarser and cheaper than for any other kinds of glass; and, in consequence of this very coarseness or want of refining, the elements which enter its composition are more numerous, consisting, as already stated, of silica, lime, potassa or soda, oxides of iron and manganese. These last oxides communicate a color to this glass, which owes, at the same

time, a part of its characteristic hue to the charcoal. Indeed, as the color of bottle-glass may be considered as essential to it, or at least does not injure its sale or diminish its value for the purposes to which it is applied, no decoloring materials are used, and it is melted in open pots, even when coal is used as the fuel, which is always the case in this country. The omission of decoloring materials forms the distinguishing feature in the manufacture of ordinary bottle-glass.

Materials.—The English laws, till lately, prohibited the use of fine materials for making ordinary bottles. Nothing but the common river sand and soap-boilers' waste was allowed. About three parts of waste, consisting of the insoluble residuum of kelp, mixed with lime and a little saline substance, were used for one part of sand. This waste was first of all calcined in two of the fire arches or reverberatories reserved for that purpose, called the coarse arches, where it was kept at a red heat, with occasional stirring, from twenty-four to thirty hours, being the period of a journey or *ournée*—a day—in which the materials could be melted and worked into bottles. The roasted soap-waste was then withdrawn, under the name of ashes, from its arch, coarsely ground, and mixed with its proper proportion of sand. This mixture was now put into the fine arch, and calcined during the working journey, which extended to ten or twelve hours. Whenever the pots were worked out, that frit was immediately transferred into them in its ignited state; and the founding process proceeded with such despatch, that this first charge was completely melted down in six hours, so that the pots might admit to be filled up again with the second charge of frit, which was founded in four hours more. The heat was briskly continued, and in the course of from twelve to eighteen hours, according to the size of the pots, the quality of the fuel, and the draught of the furnace, the vitrification was complete.

At the present time, in choosing ingredients for bottle-glass, economy is the chief object; color and appearance are here of no moment. Little soda or potassa is admitted into the composition of this description of glass; and, as the carbonates of these bases are costly, it is usual to employ in the bottle glass-works only recent ashes or wrack-soda to furnish the alkali. Moreover, the other materials are taken in a state of impurity fit only for bottles.

The primary materials of the manufacture of this kind of glass are yellow and ferruginous sands, residues proceeding from the lies of the soap and soda works, lixiviated ashes, common ashes, wrack sodas, and clay.

The colored sands are even preferable to *white sands* for bottle-glass, the oxide of iron, which colors them, performing the part of a flux. They do not require any washing or other preparation; nevertheless, any coarse foreign substances, such as pyrites, flints, &c. *cetera*, are separated from them. For this purpose they are dried, and passed through a sieve. The clay best adapted for bottle-glass is a yellow marly earth; it is furnace-clay, containing, therefore, alumina, silica, carbonate of lime, oxides of iron and manganese; it has not much of a binding quality, and is easily reduced to powder when dry, which facilitates the mixtures.

The ashes are generally obtained from common

domestic fires. Those are preferred on the Continent which proceed from the combustion of new wood or charcoal. They are sifted and dried before using. The wrack-soda is employed in a powdered state; it is even passed through a very close wire sieve.

The following is given by DUMAS as the usual proportion of these materials:—For

ORDINARY FRENCH BOTTLE-GLASS.

30-40 pounds.....	varec.
160-170 "	lixiviated ashes.
80-40 "	fresh ashes.
80-100 "	clay containing iron.
100 "	broken glass.

The proportions in English bottle-glass are slightly different:—

ENGLISH BOTTLE-GLASS.

100 pounds.....	lixiviated ashes.
40-90 "	kelp.
30-40 "	wood-ashes.
80-100 "	clay.
100 "	cullet.

The amount of cullet is not particular; it is increased for the first and second melting, when new pots are used. If a very argillaceous sand is employed, it is necessary to suppress the clay, and supply lime by a suitable addition of chalk. Natron or crude soda may be used to replace the potassa yielded by the varec; but in this case care is taken to add to the mixture a certain quantity of fresh ashes, that the glass may not be wanting in potassa.

The proportions given in the preceding recipes, as well as in those that follow, are calculated for one hundred pounds of sand:—

FOR CHAMPAGNE BOTTLES, ACCORDING TO JAHKEL.

200 pounds.....	felspar.
20 "	lime.
15 "	common salt.
125 "	iron slag.

ORDINARY GREEN BOTTLE-GLASS.

72 pounds.....	lime.
280-278 "	lixiviated wood-ashes.

DARK GREEN BOTTLE-GLASS.

20 pounds.....	dry Glauber's salt.
18 "	soap-boilers' flux.
1 "	Scheffel-Pruss.—lixiviated ash.
89 "	glass from the hearth.
179 "	green cullet or broken glass.
45 "	basalt.

Melting.—The melting-furnace for bottle-glass commonly contains only six pots. These are about three feet in height, and nearly the same in diameter. They are filled almost to the edges; and when the matter has sunk down, and is converted into a glass, more of the composition is put into the pots, and the fire is urged. The meltings are rapid; for as most of the bottle-glass compositions furnish but little glass-gall, no time is lost in fining. The process lasts from seven to eight hours, and, when it is concluded, the fire is slackened, that the glass may thicken to the point suitable for working it. For this purpose the fire-place is heaped up with small coal, draughts are intercepted as much as possible, and care is taken not to touch the fire during the working of the glass, lest the combustion should be re-excited.

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Mechanical Operations.—The working or shaping of bottle-glass is very simple in principle, and yet the operations involved are somewhat complex in detail. These may be summarily stated as follows:—The assistant collects or *gathers* on the end of the pipe—Fig. 145—the requisite body of glass, and passes it to the blower. The latter, by blowing and constantly turning the pipe, gradually forms the body of the bottle, which is finished in a mould. While the bottle is in the mould, the workman continues to blow and to turn. He then raises the pipe, and, holding the bottle in a vertical and reversed position, he depresses or hollows the bottom. The bottle is then cut at the neck, and the iron rod termed the ponty fixed at the opposite end of it; the edge of the neck is rounded, and the ring or cord which encircles it is put on, as also the seal, if the bottle is intended to have one. The ponty then passes into the hands of the assistant, whose duty it is to carry it to the annealing furnace. He there detaches it from the rod by a slight blow.

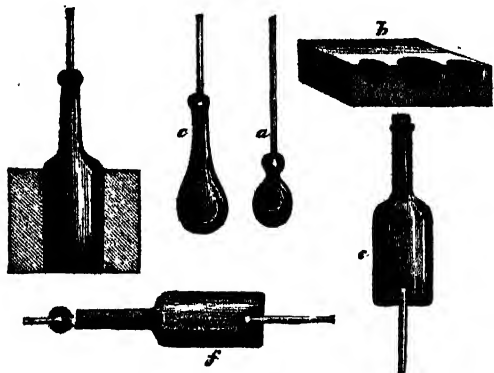
Such are the chief operations of the process of bottle-making, as described by DUMAS; but as this manufacture affords a good instance of the dexterous manipulations which are practised in blowing glass, a subject deeply interesting to the practical chemist, the following more detailed account, which is given by KNAPP as descriptive of the mode of working carried on in Spessart, will be not unacceptable to the reader:—

As soon as the working holes are opened, and the surface of the glass is cleared from sandiver or glass-gall, the workman attaches as much melted glass to the end of the pipe as he considers necessary for the production of a single bottle; his eye and hand are here unfailing guides as to the requisite quantity. By dipping the previously warmed pipe into the pot, a little glass remains attached to the end; after turning this in the air before the hole until it is cooled, and blowing slightly into it to render it hollow, a fresh layer of glass may be attached to it in the pot; to this, a third is added in the same manner, until the ball at the end of the pipe has accumulated to a sufficient size, *a*—Fig. 148. That this ball may become uniformly tractable in the subsequent forming, it is held by the workman in the flame of the furnace through the working hole; it is then brought into one of the round concavities of the *marver*, *b*, which is wetted or moistened when used. Here the ball gradually assumes the form of a thick hollow globe, or rather pear-shaped vessel. It acquires this shape by the constant rotary motion given by the workman to the pipe, whilst the cooling and stiffening of the mass is rendered uniform by the marver, and is prevented shrinking together by constantly blowing into the tube with very little force. The mass of *metal*, which, as already stated, is the technical term applied to glass during working, must be equally distributed round the axis of the instrument, and advanced in front of its mouth, being connected with it only by a short neck. Towards the front part, where the subsequent widening occurs, and the mass is blown out, it is thickest; the portion nearest the pipe is less massive.

Thus far advanced, the glass has again become cool, and is re-heated by insertion into the working hole, in such a manner that the front part receives the chief

portion of the heat, and becomes the softer. The pear-shaped vessel is now lengthened by the blower, and its form is made somewhat to resemble that of a bottle by a threefold operation: by blowing into the tube with greater force, *swinging* it backwards and forwards in the manner of a pendulum, and by a simultaneous constant rotary motion of the pipe round its axis. The globular form which the glass tends to assume under the influence of blowing, is converted into a long, thin egg-shape, *c*, by the swinging motion, and so much the more

Fig. 148.



as the lower temperature at the extremity is less favorable to the formation of a globe, than to the lengthening of the neck. The rotation round the axis of the pipe is an essential part of every operation in glass-blowing. The glowing mass of glass creates a powerful current of air in an upward direction, and the lower portion becomes cooled in consequence much more than the upper. This naturally creates an inequality in the resistance offered to the blowing, and the upper portion would be more expanded than the lower, if the cooling influence were not allowed to act upon all parts of the surface alike, by the revolving motion of the pipe, and this is particularly the case when the latter has to be held in a horizontal position. The mould, *d*, which is a simple cylindrical hollow block of wood or iron, is placed at the side of the workman who is blowing the pear-shaped vessel; into this he inserts the vessel as soon as it has acquired the proper thickness, in the manner represented in the figure, and by blowing forcibly into the tube, he presses the glass firmly against the sides of the mould, whilst, by a kind of jerking motion, the neck is drawn out to the proper length. The unfinished bottle, which as yet has no bottom or mouth, is again warmed in the working hole in such a manner, that the lower part only is heated, whilst the other part remains comparatively cool. In the meantime, another workman or a boy has attached a small quantity of glass to the ponty or pontil, which is also kept hot in the working hole. Both workmen now stand opposite to each other; and whilst the pipe and ponty are kept constantly turning, the latter is forcibly pressed against the middle of the lower part of the bottle, which is thus forced inwards, and an even edge is produced, upon which the bottle may stand steadily. The bottle remains for some moments between the two instruments, as shown at *f*, until, by the application of cold iron or a drop of water,

the neck can be separated from the pipe. This is an operation of constant recurrence in the glass-house, and is effected by a sudden change of temperature produced at the point of separation in the hardened glass, either by the cold application of a drop of water, or by the powerful heat of a red-hot iron, or thread of liquid glass from the pot. The point of separation must often be re-heated, to cause it to fly on the application of cold water. The bottle is now supported by the ponty, as shown at *e*, so that the neck can be warmed, and the sharp edges melted round without softening the other parts. A rotating motion is then given to the red-hot neck, the pipe being rolled backwards and forwards upon the knees of the workman. The bottle then revolves upon its axis, as if it were placed in a lathe, and it is only necessary to press the pucellas, *b*—Fig. 146—or an iron instrument like a turning chisel, against the mouth, to widen or reduce it to any required dimensions; the rim for strengthening the neck is formed from a drop of glass taken from the pot by the edge of the flask, and wrapped round the mouth in the form of a thick thread. The bottle, which is now finished, as shown in the last cut, is immediately carried on the ponty-rod to the annealing-oven by a boy, pushed into its proper place, and the ponty-rod is finally detached from the bottom of the bottle by a sudden sharp jerk. The place where the ponty was attached is perceptible in every bottle blown in this manner, by the sharp edges where the fracture occurred.

Large round bottles are blown without the use of a mould, and when of a very great size, like the carboys for sulphuric acid, the aid of steam is called in, by spirting about an ounce of water into the interior, and holding the mouth of the pipe with the thumb. Bottles in the shape of a flattened globe, are also made without any mould by simple blowing. The preparation of the mass of glass, the formation of the concave bottom and of the neck, is in this case effected in precisely the same manner as above; the swinging motion, however, must not be continued for such a length of time, as the bottles required are shorter. In blowing the belly of the bottle, the workman stands in front of a slanting board, and presses the globe, as it is gradually formed by slow blowing, against the board at every half revolution of the pipe; the flat surfaces on opposite sides are thus produced.

As the greater number of bottles are necessarily sold with a legal stamp upon them, and as their capacity must be suited to the standard measures of the country, the fulfilment of these conditions presupposes an extraordinary degree of dexterity and correctness of eye in the blower. Attempts have consequently been made by many inventors to furnish the bottle-maker with a mould of such construction as would enable him to secure the formation of a bottle, perfect, both as regards form and capacity, at one single operation, without reliance upon his own correctness of sight. The use of moulds of this description, like that of RICKETS, which is easily managed, affords a great saving of time, and the repeated heating of the bottles is unnecessary. The mould consists of a body, which forms the belly of the bottle, and of four other parts, a fixed bottom-

piece with a movable piston for forming the concavity, and two movable pieces for the neck. Two treadles set these different parts in motion. As soon as the workman has introduced the hollow lengthened globe into the belly of the mould, by pressing with his foot upon the first treadle, he brings up the neck piece, then forces the glass into contact with all parts of the mould by a powerful blast, and finishes the bottle by working the second treadle, which forces the pestle against the bottom. On the removal of the pipe, the rim is all that remains to be perfected.—*Knapf*.

The circle of operations above described is continued with much quickness, four or five men being able to make a hundred wine bottles in an hour; and, with a few modifications, according to the size, shape, and purpose of the bottles, may be taken as a general exemplification of the mode of proceeding. The vicinity of the Tyne on the Wear is abundantly supplied with many of the requisites for bottle-making, and hence the manufacture is there largely carried on.

Champagne and Aerated Water Bottles.—The uses of bottle-glass do not require to be explained in detail, but it is necessary to say a few words with reference to bottles intended to resist a high pressure, such as those for holding champagne, and still more in this country for holding aerated waters, which are now manufactured in immense quantities. Bottles employed for such purposes undergo an internal pressure, which readily produces the fracture of weak vessels, and this occasions a loss which is always considerable, and often disastrous. It is evident that this might be diminished by testing all the bottles under a pressure the double of that to which they are intended to be subjected, and accordingly different machines have been invented for this purpose, by means of which water is forcibly pumped into the bottles, until the indication of the manometer shows them to have withstood a sufficient degree of force. DUMAS states that, from the experiments made by the *Société d'Encouragement*, champagne bottles were found to stand only when they were capable of supporting a pressure of twelve atmospheres. He adds that the mode of filling and annealing, as well as the form of the bottles, must exercise a great influence, which it would be necessary to find the means of estimating; also, that perhaps it would be desirable to leave a larger unfilled space in the bottles, and to use them only after a careful annealing in boiling water. *KNAFF* remarks, that although every bottle, when quite filled with water and containing no air, will burst in the belly from a slight blow on the cork, in consequence of the sudden force being communicated from the liquid to the sides, yet champagne bottles will often withstand a pressure of forty atmospheres and upwards, equal to six hundred pounds on the square inch.

II. WHITE BOTTLE OR CHEMICAL GLASS.—Under this head may be included white glass for medicinal bottles and chemical purposes, refractory Bohemian glass for tubing, *et cetera*, and foreign crown. The most beautiful material for bottles is furnished by flint-glass or crystal, but these are only intended for ornamental articles or vessels for the table, and will be alluded to under Flint-glass.

The general character of white bottle-glass consists

in this, that it is composed of purer materials than the green; decoloring matters are used, and the materials are selected as free from iron and alumina as possible. Moreover, in this case the glass is subjected to a thorough fining process. The following are given by *KNAFF* as general standards of composition for different varieties of glass of this description:—

FOR APOTHECARIES' PHIALS.

100	pounds white sand.
30-35	" potassa—impure.
17	" lime.
110-120	" ashes.
25-35	" binoxide of manganese—cullet.

BOHEMIAN CRYSTAL FOR GRINDING.

100	pounds white sand.
0-60	" purified potassa.
8	" chalk.
40	" broken glass.
75	" manganese.

SEMI-WHITE.

100	pounds sand.
100	" crude soda, containing lime.
100	" cullet.
5-1	" manganese.

100	pounds sand.
30	" potassa.
18	" lime.
	decoloring matters.

CLEAR WHITE.

100	pounds sand.
65	" calcined potassa.
6	" fallen lime.
100	" white cullet.
5	" manganese.

WHITE GLASS FOR CHEMICAL PURPOSES.

100	pounds white sand.
41.4	" potassa.
17.5	" lime.

Bohemian Glass.—The coarser qualities of this kind of glass are analogous in composition to bottle-glass, and are distinguished by comparative freedom from color, great lightness, and their very refractory nature, which renders them capable of resisting not only high heats, but sudden changes of temperature. Hence the value of this glass for chemical purposes, such as tubing, retorts, *et cetera*. Its lightness, and the almost total absence of coloration—when it is made with pure materials—cause it to be highly valued on the Continent for tableware, where it is also employed to make costly windows for fine buildings and carriages, for covering engravings, and in general for all those uses which require the glass to have a considerable thickness without coloration. In common with crown-glass, it is also peculiarly fit for optical instruments, in which it is employed to achromatize the flint-glass. These remarks apply to the finer qualities, for which DUMAS gives the following choice of proportions:—

Quartz in powder, or fine silicious sand	100	110	120	100
washed with hydrochloric acid,	60	64	66	75
Purified carbonate of potassa,	20	24	25	50
Very pure carbonate of lime,				

In a Bohemian glass of old manufacture, DUMAS found

Silica,	69.4	=	36	oxygen.
Alumina,	9.6	=	4.48	9.04
Lime,	9.2	=	2.57	oxygen of
Potassa,	11.8	=	1.99	the bases.

which would give exactly the proportion of 1 : 4 between the oxygen of the bases and that of the acid. On the whole, Bohemian glass may be described as a silicate of potassa and lime, with a small proportion of alumina, magnesia, and other ingredients. This will be obvious from the following analysis of a glass, taken by M. PERDONNET from a manufactory at Neuvelt, and analysed by M. GROS in the laboratory of the School of Mines at Paris:—

Silica,.....	71.6	=	37.1	Oxygen.
Lime,.....	10.0	=	2.81	
Potassa,.....	11.0	=	1.86	
Alumina,.....	2.2	=	1.02	
Magnesia,.....	2.3	=	0.89	
Oxide of iron,.....	3.9	=	1.20	
Oxide of manganese,.....	0.2	=	0.05	
<hr/>				
	101.2			

Here it will be noted, that the silica contains about five times the aggregate oxygen of the bases. It will be observed also, that in Bohemian glass potassa takes the place of soda.

Tube-drawing.—Though tubes may be formed of any kind of glass, yet, for chemical purposes, and more especially for resisting a high temperature, the Bohemian or German tubes are the best. This may, therefore, be a fitting place to introduce some account of the curious operation of *tube-drawing*, which depends on the singular fact, that when a hollow lump of glass, for instance a globe, is drawn out whilst hot, the cavity in the interior is always preserved, even when the glass is drawn out to the tenuity of the finest thread. The operation is described by KNAPP in the following terms:—

Whilst one man collects the necessary quantity of glass on his pipe, and blows this out to a very massive globe, preserving a uniform thickness of the sides as much as possible—Fig. 149—the other attaches a drop of glass to a ponty-rod, and warms it on the fire by the side of the globe. Both instruments are then removed from the fire at once, and the ponty-rod is pushed forcibly against the globe in such a manner as to form exactly a straight line with the pipe, as represented in Fig. 150,

Fig. 149.

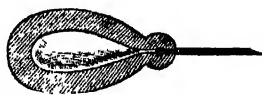


Fig. 150.

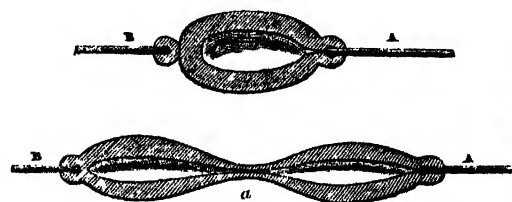


Fig. 151.

where A is the pipe, and B the ponty. This being accomplished, one of the workmen retires backwards as quickly as possible, to the distance of fifty, sixty, or one hundred feet. In this operation the globe at first shrinks, as is represented at a, in Fig. 151, and forms the commencement of the tube, which soon cools, and does not diminish in thickness, whilst the mass of glass is spun out by the constant drawing

from the warm end. Continual rotation of the pipe and ponty-rod is here as necessary as in all the other operations of glass-blowing, or the part of the tube nearest the ground would cool quickest, and the tube thus assume an irregular form. This, however, does not prevent the tube, in consequence of its great length, from sinking in the middle like a stretched rope, and it becomes, consequently, thicker at the two ends, as is represented in Fig. 152. The curve in the tube is, however, remedied by placing it on a ladder before it has become perfectly set; it then straightens, and is

Fig. 152.



cut into lengths of four or six feet each, by taking hold of it with a cold pair of tongs. Tubes cool very uniformly, in consequence of their small amount of metal, and they are, therefore, not placed in the annealing oven. Lastly, the bore of the tube is dependent upon the length to which a given mass of glass is stretched, or, the length being the same, upon the mass of glass; the stoutness of the tube is, however, determined by the thickness of the sides of the original globe, as the relation between the thickness of the sides and the bore is not altered by drawing. Wide, thin tubes—such as are used for spindles, *et cetera*—must therefore be drawn out of a large thin globe, and *vice versa*: it is necessary, however, whilst the tubes are drawing to blow into them, that the sides may not sink in. —Knapp.

Foreign Crown-Glass.—The name of crown-glass is limited in this country to that which is formed into circular tables by the process of blowing; but the crown-glass of the Bohemian glass-houses assumes the variety of forms which belong to articles of luxury and art, and is generally moulded into different shapes, with a view to grinding and polishing. Regarded in this light, the foreign crown, properly so called, is rather distinguished by its composition, than by the methods of manipulation adopted in its manufacture. Like the coarsest Bohemian glass, it is a silicate of potassa and lime; whereas, in the English crown, soda is employed, either in the shape of sulphate or carbonate. DUMAS analysed a good crown-glass of German manufacture with the following result:—

	Centesimally.	Oxygen.
Silica,.....	62.8	= 32.6
Alumina, oxide of iron and of manganese, 2.6	=	1.2
Lime,.....	12.5	= 3.5
Potassa,.....	22.1	= 3.7

So that in this case the silica contained about four times more oxygen than the bases, and the quantity of oxygen in the lime and potassa, the two principal bases, was nearly the same. As this glass is chiefly manufactured for the same uses as crystal, it is better prepared by means of suitable moulds than by simple

blowing, partly because the forms required are frequently so complex as scarcely to admit of their being made by hand, and partly because the various indentations and projections upon the surface can be roughly given by means of a mould, and time and trouble are thus saved in the subsequent laborious operations of grinding.

As the beauty and value of this glass depend upon its absolute limpidness, the most careful selection of materials, both for the mixture and the pots, and a protracted and assiduous process of fining are required. Speaking of foreign crown-glass, DUMAS remarks that it is not an easy matter to arrive at a certainty of success in its manufacture. It is evident, he adds, that to obtain it without color, one must use potassa, and not soda. Even if the soda yielded a colorless glass, it should still be put aside on account of the facility with which glass having a soda base devitrifies, which would render the thick masses that require a long cooling quite milky, and full of crystalline and opaque nodules. Crown-glass should therefore be formed with a potassa base, and without oxide of lead; but lime must also be added. By forming a glass with merely a potassa base, there would be no danger of devitrification; but the glass would be soluble in boiling water, and consequently hygrometrical. This would be a serious disadvantage; for spectacle-glasses or other lenses so formed would constantly tarnish by the deposit of a film of aqueous vapor, and in the space of a few years would altogether lose their polish. This inconvenience is avoided by adding to glass with a base of potassa a certain quantity of lime; but then arises a not less serious evil—a proneness to devitrification. Glass with a base of potassa and lime, submitted to the prolonged annealing which thick masses intended for large lenses require, is apt to assume the milky aspect which indicates a commencement of crystallization in the mass. Thus the manufacture of crown-glass, as well as that of flint-glass—the two glasses indispensable for the preparation of achromatic objectives—both present the most serious difficulties, although from very different causes.

III. WINDOW-GLASS.—The glass which has long been in common use for window-panes is that which is generally known as *English crown-glass*, in the manufacture of which a large globe is first blown at the end of the pipe, and this is converted by a rapid rotatory motion into a circular plate or disc thickened at the centre. Until a comparatively recent period this was the only method employed in the manufacture of window-glass in this country; but latterly the Continental method has been extensively introduced, which consists in forming the globe into a cylinder, and then, after cutting it up in a direction parallel to the axis, flattening it out into a broad sheet, from which it has received the designation of *British sheet-glass*. *Plate-glass*, or that which is cast into sheets by pouring the liquid metal on a flat surface, is now beginning to be much used for the same purpose, especially for the windows of shops and fine buildings; but as the chief demand for plate-glass is still for mirrors and other similar articles, this will be treated under a separate head, and in the meantime

the term window-glass will be considered as confined to *English crown* and *sheet-glass*, which are composed of precisely the same materials, and differ only in the mechanical operations by which they are brought into form. Chemically speaking, they are the same, except that the nature of the crown-glass manipulation requires a smaller quantity of lime. Plate-glass, on the other hand, is formed with a larger proportion of alkali.

Composition.—The materials employed for the manufacture of English crown and sheet-glass—in other words, of window-glass—are chiefly silica, soda, and lime. This glass differs, therefore, from the foreign crown and Bohemian glass in the circumstance, that soda, as the cheaper alkali, is generally substituted for potassa. Sometimes, however, though rarely, a mixture of the two is employed. Alumina, oxide of iron, and oxide of manganese are also found in window-glass, but only as accidental ingredients. It is true, indeed, that when iron is present, as is almost always the case, the binoxide of manganese is purposely introduced to neutralize its effects; and a little arsenic is generally added to promote the decomposition of the other ingredients.

Mr. HENRY CHANCE, one of the highest authorities on this subject, remarks, that to lay down any standard proportions for window-glass is almost impossible, as no two manufacturers use the same; and even in the same works the melting powers of the furnaces may so far differ as to render necessary, for the production of the same glass, variations in the proportions of its elements. RICHARDSON and RONALDS give the following as the mixtures used in some English manufactories:—

	Pounds.	Pounds.	Hundredweights.
Sand,.....	560	448	16
Chalk,.....	154	146	5
Carbonate of soda,...	119	168	5
Sulphate of soda,....	63	17	1.25
Arsenic,.....	2	2	0
Cullet,.....	48	448	16

The introduction of carbonate of soda, prepared from salt, into the glass manufacture of England, dates from the year 1831. Previously to this, kelp was employed as the source of alkali. In the meantime, the French manufacturers—released, in 1825, through the exertions of M. CLEMENT DESORMES, from the absurd veto which the government had pronounced on the sale of sulphate of soda—were enabled to turn their attention to the employment of this salt instead of the carbonate. They proceeded with caution in the introduction of the new ingredient—first mixing a small quantity of sulphate with a large proportion of carbonate; then half of each; and, finally, excluding carbonate, they adopted the sole use of sulphate, to the injury, doubtless, of the color of their glass, but gainers by the employment of a cheaper and more manageable material. Where absence of color, however, is an object, as in the manufacture of plate-glass, the exclusive use of carbonate of soda is still retained.

Proceeding cautiously in the steps of their foreign brethren, says Mr. CHANCE, the English glass-makers, after they had established the use of carbonate, made trial of the effect of a small quantity of sulphate of soda in a large quantity of carbonate. The carbonate gradually decreased, until at length, in the preparation of

blown window-glass, sulphate generally stood alone. But here, as abroad, the manufacturers of plate-glass still adhere to the carbonate. The preceding table of three different proportions for crown-glass evidently refers to a period when the carbonate still preponderated in this manufacture also. As the use, whether of carbonate or sulphate of soda, involves their preparation from common salt and sulphuric acid, attempts have been made to accomplish the direct union of silica and salt in the manufacture of window-glass, but have hitherto failed of success. The black bottles of Newcastle are made from common rock salt and sand from the bed of the river, with the carbonate of lime of the soap-works, and the tank waste of the alkali-makers; but for all better kinds of glass the circuitous combination of silica and alkali is still found necessary.

The following is a French composition, which gives, according to DUMAS, a window-glass of fine quality:—

	Parts.
Sand,	100
Chalk,	35 to 40
Dry carbonate of soda,	28 to 35
Broken glass,	60 to 180
Binoxide of manganese,	0.25
Arsenic,	0.20

The oxygen of the bases in this glass is generally to the oxygen of the acid as one to four.

M. BASTENAIRE gives the three following compositions, which DUMAS considers too rich in alkali, and too poor in lime:—

I.	Parts.
White sand,	100
Good potassa,	65
Lime slaked in the air,	6
Fragments of white glass,	50
Arsenious acid,	1
Oxide of manganese,	0.30

II.	Parts.
Very white sand,	100
Good soda,	90
Red oxide of lead or minium,	5
Broken white glass,	100
Carbonate of lime,	5
Oxide of manganese,	0.40

III.	Parts.
White sand,	100
Good soda,	80
Carbonate of lime,	8
Broken glass,	110
Oxide of manganese,	0.20
Oxide of cobalt,	0.10

In none of these French receipts is the sulphate introduced, and therefore they may be referred to a period anterior to 1825, when, as already remarked, the sulphate began to be generally adopted in the French glass-works. DUMAS remarks that the object to be kept in view in employing this salt, is to render its decomposition by the silica as quick and easy as possible; and he adds, that this is managed by adding to the mixture a suitable quantity of charcoal, to transform the sulphuric acid into carbonic and sulphurous acids. Thus—



For each equivalent of dry sulphate of soda there

is required, therefore, one equivalent of charcoal, or else about six of charcoal for seventy-two of sulphate of soda. But to avoid coloring the glass yellow, only five equivalents of charcoal are employed. Thus, to produce a beautiful window-glass, continues the same writer, the following proportions are taken:—

	Parts.	Parts.
Sand,	100	100
Dry sulphate of soda,	44	58 to 75
Charcoal in powder,	4	4.5 to 5.5
Slaked lime,	6	13 to 15
Broken glass,	from 20 to 100	25 to 100

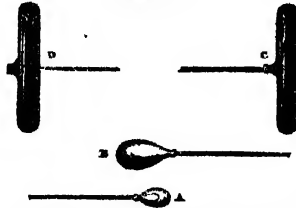
Mechanical Operations.—It has been stated that the difference between English crown and cylinder or sheet glass, is almost entirely in the manipulation. The above materials and proportions apply to both, inasmuch as the two are the same window-glass in the pot. The specific description of these two varieties, if they may be so distinguished, involves, therefore, only a series of mechanical operations, which do not strictly belong to the special object of this work. Yet, as the present article would be incomplete without such details, the Editor will here introduce a short account of both processes, beginning with crown-glass as the oldest; and, in doing so, he begs to acknowledge his obligations to Mr. HENRY CHANCE, by whose kindness he is permitted to present the reader with the following animated account of the mechanical part of the manufacture, from a paper which was read by that gentleman before the Society of Arts, in January, 1856.

1. *English Crown Glass.*—Assuming one or other of the mixtures or compositions above given to be melted in the crown-glass pot, represented in Fig. 141, Mr. CHANCE begins by observing, that upon the surface of the melted glass is a ring of fire-clay, which, when the materials were thrown in, lay at the bottom of the pot, and after the completion of the melting, found its way upwards. This ring is of great service, for, floating in the centre of the pot, it prevents the exterior surface of the metal, or melted glass, which becomes stiff and stringy during the long period of working, from mingling with the interior or hotter surface, which thus remains throughout of a suitable consistency. The labor, also, of the skimmer, whose duty it is to clear the surface of the metal from any scum or dirt that may collect upon it, is considerably diminished by the ring, which, limiting the space from which the glass is drawn, limits also the space which it is necessary to cleanse, and any bubbles or impurities in the glass have a tendency to attach themselves to the ring.

The metal, or melted glass, having been brought, by the gradual cooling of the furnace, from a state of complete fluidity to a consistence capable of being worked, the gatherer dips the end of his pipe, or hollow rod of iron, into the pot inside the ring, and twirling it round its axis, to equalise the thickness of the gathering, collects upon the end, or nose, as it is technically called, a pear-shaped lump of glass, similar to that represented at A, Fig. 153. Resting his pipe upon a stand or horse, he turns it gently round, and allows the surface of the lump to cool, to fit it for a second gathering. So much glass is collected in this way, in successive layers, as will form a disc or table of about nine pounds weight,

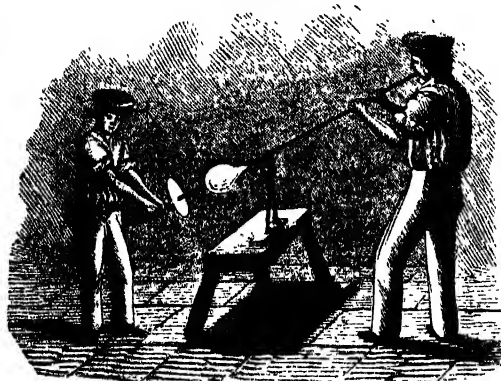
and an experienced workman seldom fails more than an ounce or two in the correct weight. The lump completed, the gatherer, having cooled his pipe under a

Fig. 153.



trough of water, that he may handle it at any point, proceeds to roll the glass upon the marver, or metallic bed, until it assumes a conical form, the apex of the cone forming what is termed the *bullion-point*. A boy now blows down the pipe while it is still being turned by the gatherer on the marver, and expands the glass into a small globe. Having been heated, it is blown again, and assumes the shape of a Florence flask, as shown at *r*, and the future rim of the developed plate or disc is prepared by rolling the *piece*, as the glass under operation is technically termed, near the pipe nose, upon the edge of a marver. Again heated, it is now expanded by the blower into a large globe. During this expansion, it is important to keep the bullion-point exactly in the position which it previously occupied, in a line with the axis of the pipe. To effect this, the blower rests his pipe upon an iron support, and while he blows down the pipe and turns it round at the same time, a boy holds against the bullion-point a piece of iron terminating in a small cup. This operation is represented in Fig. 154. Again presented to the fire, by the peculiar manipulation of the workman, and the peculiar direction of the flame upon it, the front of the globe is flattened, the possibility of the globe collapsing during this operation being prevented by its rapid revolution round its axis. The piece now resembles somewhat in shape an enormous decanter, with a very flat bottom and a very short neck, as at *c*, Fig. 153. The bullion-point is still to be seen in the centre of the flat bottom, and its use now

Fig. 154.

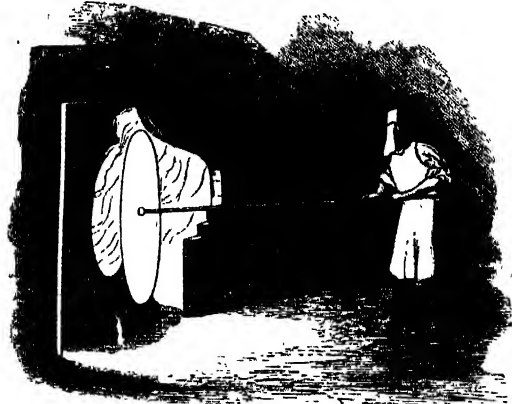


becomes manifest. The pipe is laid horizontally upon an iron rest, and a man approaches, having in his hand the large rod of iron called the ponty, tipped with a lump of molten glass. Pressing this lump upon an iron point, so as to give it the form of a little cup, he fits it, when thus shaped, on to the bullion-point, to which it soon becomes firmly attached. The lump thus formed is called the *bull's-eye*, or bullion of the

developed plate. The incision of a piece of cold iron in the glass round the nose of the pipe, and a smart blow, soon detaches the pipe, leaving a corresponding hole in the flattened sphere, at a point exactly opposite the attachment of the ponty, as shown at *d* in Fig. 153. The blowing pipe thus removed, and carrying with it a piece of glass, is allowed to lie idle a few minutes, till the glass adhering to it has cracked off; it is then warmed, and carried back to the pot to repeat its course in a similar operation.

The open projecting end of the piece, which was next the now detached pipe, is called the nose, and gives its name to the furnace or nose-hole, where this nose is, on account of its thickness, heated almost to melting, with a view to the next operation. It is now that the glass

Fig. 155.



undergoes its last and most dreadful torture in the hands of a man who, with a veil before his face, as shown in Fig. 155, stands in front of a huge circle of flame, termed the *flashing furnace*, into which he thrusts his piece, rapidly, meanwhile, revolving his ponty. The action of heat and centrifugal force combined is soon visible. The nose of the piece, or hole caused by the removal of the blowing pipe, enlarges, the parts around cannot resist the tendency, the opening grows larger and larger; for a moment is caught a glimpse of a circle with a double rim; the next moment, before the eyes of the astonished spectator, is whirling a thin transparent circular plate of glass, which, but a few minutes before, was lying in the glass-pot, an indistinguishable portion of the molten mass. The sound of the final opening of the piece has been compared to that produced by quickly expanding a wet umbrella. In this way a flat circular disc, nearly sixty inches in diameter, or sometimes more, is produced, of almost uniform thickness, except at the point of attachment to the ponty, where there is a swelling called, as already stated, the bull's-eye. The glass at the edge of the disc is also in some cases a little thickened. Still whirling, the *table*, as it is now called, is carried off, laid flat upon a support called a whimsey, detached by shears, or otherwise, from the ponty, lifted into the annealing kiln upon a fork, *e*—Fig. 146—and piled upon its edge against the preceding table. The weight of so many tables pressing one against another, would cause the hindmost to bend; but this is prevented by the intervention of iron frames, or dros-

sors, which divide the tables into sets, the first drosser leaning against the wall of the kiln, the second against the first, and so on; and thus rendering each set of tables independent of those behind it for support. As the bull's-eye, or centre lump, which the ponty has left behind it, keeps each table from close contact with its neighbors, the air passes freely between them, and the annealing is completed with tolerable rapidity, varying from twenty-four to forty-eight hours, according to the number of tables in the kiln. From the kiln the tables are conveyed to the warehouse, having passed, since their first exit from the pot, through the hands of ten distinct workmen.

Such, with a few slight additions and illustrations, is the description of this most interesting process given by Mr. HENRY CHANCE. He adds that the process may be regarded as twofold—first, the development of the lump into a sphere; and, secondly, the resolution of a sphere into a circular table. Constant rotation of the glass, while in a yielding state, is an essential element of this process; as, if allowed to remain motionless, its symmetry would be immediately destroyed.

A table of crown glass of to-day, would scarcely recognise as of kindred origin a table of the earlier part of the present century. The principle of the process in each case was the same; it is the improvement of minute details that produces so different a result. To Mr. HARTLEY and Mr. CHANCE, who, during the years 1832 to 1836, gave to the manufacture of this glass their constant attention, is owing, in a great measure, its present status.

When the tables of crown-glass are drawn from the kiln, they are covered with a whitish film or *hum*. The history of this hum, continues Mr. CHANCE, is curious. It arose, probably, in the first instance, from the deposition of sulphur from the fuel upon the surface of the glass. It thus became associated with the process of annealing, and buyers fancied that the more hum there was upon the glass, the better was the glass annealed. The manufacturers of crown-glass, ever ready to accommodate themselves to the fancies of their customers, have taken the trouble to produce an additional hum by the introduction of sulphur in the kiln. The members, however, of the Glass Jury of the Paris Exhibition, not being in the secret of this hum, stontly maintained that glass thus clouded must be bad glass, and that the hum was owing to the exudation of the alkali.

In the warehouse, the tables are laid upon a *nest*, or cushion, and are divided by the diamond of the splitter into two unequal parts—the larger half containing the bull's-eye. The diameter of the table is measured on the nest, the usual size being now about fifty-four inches, and weighing thirteen pounds. Tables have been made as wide as seventy inches, but the difficulty of manipulation, and the uncertainty of the result, render such sizes too costly to be general.

The splitter carefully examines each table before splitting it, and turns it round till he has brought it into the position in which he may split it to the best advantage, announcing at the same time its quality. The first quality is called *best*—the next, *seconds*—then *thirds*—*fourths*—*CC*—*CCC* or *Irish*—and tables con-

taining any very glaring defects, come under the denomination of *coarse*.

These variations in quality depend on the presence or absence, number and extent, of those defects to which, even in the best regulated manufactories, glass is unavoidably liable. Perhaps the glass has been badly melted, and is *seedy*—that is, full of little vesicles, to which the rotary motion has given a circular shape. Or the gatherer may have enclosed air within his *metal*, and a gatherer's blister is the result; or a pipe blister, or pipe-scales, or dust from the pipe-nose, or dust from the marver, or dust from the bottoming-hole, or dust from the nose-hole, or dust from the flashing-furnace, or bad bullions, or scratches, or music lines, may disfigure the table, or the glass may be crizzled, or curved, or bent, or hard, or smoky, or small and light, defects to explain which would be a long and dreary task. No wonder that tables of the best quality are few and far between, in some manufactories a forlorn hope never to be realized.

The difficulty of obtaining glass free from defects will account for what may at first astonish—the fact that the value of a table of the highest quality is three times that of the lowest.

The defects enumerated, many as they are, are instantly detected, even through the obscuring hum, by the splitter, who not only can descry faults invisible to ordinary eyes, but can refer each fault to a particular stage of the process, and to a particular cause in that particular stage, and the faults are registered accordingly. The nomenclature of defects is much facilitated by the mapping out of the table into certain ideal divisions, derived from shapes assumed during various periods of the process. The centre lump is termed the *bullion*, round this lies the *bottom*; next the *bulge*; the *shoulder*; the *top*, and the *rim*, or the outermost edge of the circle.

Independently, however, of these defects, there are certain other disadvantages under which even a faultless table of crown-glass must unavoidably labor. The cutting of a circle into rectangular sheets, must necessarily be attended with waste, while the bull's-eye confines those sheets to comparatively small sizes. Uniformity of thickness, also, except by the most skillful manipulation, is difficult of attainment. *Wavy lines*, termed *music lines*, forming a series of concentric circles round the bull's-eye, and owing to the treatment of the glass upon the marver, were formerly a common defect; but improvements in the process have in a great measure removed them.

On the other hand, extreme brilliancy of surface is a distinguishing characteristic of this glass, ascribed by some to the influence of the marver, by others to the effect of the flashing-furnace.

It is this brilliancy of surface which has enabled crown-glass to maintain in England its position against that formidable rival which is now to be briefly described.

Cylinder, or Sheet-Glass.—The above method of making window-glass has long been abandoned on the Continent, where the glass is first formed into a *spheroid*, the ends of which are cut off, so as to form a cylinder open at both extremities; this is then cut

lengthwise with shears, or a straight line is traced with a drop of water in the direction of the length of the cylinder, and over the line so traced a red-hot iron is passed, which immediately produces a very uniform crack or fracture along the whole length. The cylinder, thus split up, is then taken to the furnace to be spread or flattened out into a sheet. The glass so manufactured, though formed of the same materials as crown-glass, is coarser in texture, more wavy and dull, but allows of larger sheets being formed, since crown-glass can only be cut up into comparatively small panes, in consequence of its circular form and the central bull's eye.

M. BONTEMPS remarks that there is no evidence by which to determine the relative antiquity of the crown and cylinder glass processes. There is reason to believe, however, that even in this country the latter was the more ancient, although at a comparatively early period it was abandoned in favor of the rotary method. The cylindrical process is the only one mentioned by THEOPHILUS in the thirteenth century; and this method was adopted by the Venetians, as the more uniform thickness which resulted from it insured, in their colored glasses, a greater uniformity of tint. But in France, England, and the North of Germany, the cylindrical process fell gradually into disuse, as the demand for colored glass diminished, and at length in these countries the rotary principle exclusively prevailed. Bohemia, however, still retained the cylindrical method, which she had learned from Venice, and this method was reintroduced into France by M. DROLENVAUX in 1730 with great success. Hence speedily resulted, not only in France, but also in Belgium and the North of Holland, where the style of building required panes of large size, the general abandonment of the rotary principle, and the adoption of the cylindrical, which continues, as already stated, to be practised universally on the Continent at the present day.

In England the manufacture of crown-glass maintained its position, notwithstanding its abandonment abroad, and attained to such superiority over the spread or broad glass manufactured on the German principle, that the former was used for all houses of the better class, while the latter was confined to poorer dwellings. The inferiority of this spread glass, manufactured indeed on the German principle, but by no means so good as the German glass, tended to prejudice the public against all glass made by the cylindrical method. This prejudice was, however, gradually overcome, by the establishment in England of the manufacture of cylindrical glass, according to a process introduced from France, and from which resulted a glass that has entirely displaced the manufacture of spread glass. The latter was so called from the circumstance that the cylinder, unskillfully blown, and then cut open with shears, as already stated, was spread out immediately upon a plate of iron covered with sand. Hence not only was the thickness of this glass very irregular, but its surface very coarse.

The introduction into this country of the manufacture of cylindrical glass by the French method, was due to the Messrs. CHANCE of West Bromwich, near Birmingham, and Mr. HARTLEY, now of Sunderland, but then

in partnership with the Messrs. CHANCE, who, on visiting in 1830 the works of M. BONTEMPS, near Paris, were much struck with the advantages of the glass made on this principle, and having secured the co-operation of M. BONTEMPS, commenced the process at their own works in the autumn of 1832. So great, however, were the difficulties to be overcome, that it was not till 1838 that the fabrication of this glass was completely established. Since that time there has been great progress, and the sheet-glass now manufactured in this country, though inferior in color, is in other points generally superior to that of the foreign teachers. On this point Mr. BANNATYNE, in the new edition of the *Encyclopædia Britannica*, says:—The French, Belgians, and Germans, having pursued the cylindrical system for the last fifty years in making their window-glass, have much improved the old method of making it; and as the parties who are now manufacturing this article in England—namely, the Messrs. CHANCE and Mr. HARTLEY—are crown-glass makers, and have imported all the improvements adopted in the making of sheet-glass in France, Belgium, and Germany, and combined with these the improvements which their experience as crown-glass makers had taught them during the same period, they have surpassed the French, Belgians, and Germans in sheet-glass, and can now compete with them in all parts of the world.

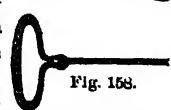
After this testimony, the following account of the process for making British sheet-glass, as given by Mr. HENRY CHANCE, one of the partners of the eminent firm above-named, will be received by the reader as of very high authority:—

Imagine, as before, a lump of glass collected upon the end of the gatherer's pipe. For the metallic table or marver is now substituted a block of wood, so hollowed out as to allow the lump, when placed upon it, to be expanded by the blower to the diameter ultimately required. The block, during this operation, is sprinkled with water, to prevent the wood from being burnt, and from scratching the glass. In the meantime the lump is slightly distended by blowing, and, having received the shape represented in Fig. 156, it is carried from the block to the blowing furnace, which is accessible through a number of holes or openings, each hole being allotted to a single blower. In front of the furnace, corresponding to each opening, is a stage or frame of wood, erected over a large pit or well about ten feet deep—as represented in Fig. 157—and these parallel stages are sufficiently apart to enable each blower to swing his pipe to and fro in a vertical plane, that the glass may run freely out, as the phrase is, to the required length. When the glass has been sufficiently heated in the blowing furnace, it is brought out, and held over the head while blown, until it assumes by its own weight the flattened form represented in Fig. 158. It is then swung round in a vertical plane, as well as backwards and forwards, and the blower at the same time, by blowing down the pipe, constantly keeps the lengthening cylinder full of

Fig. 156.



Fig. 158.



air. The first form which the glass assumes in consequence of the swinging motion is represented in Fig. 159. If the man were to blow without swinging, a

Fig. 157.



globe or sphere would be formed, as indicated by the dotted line. Uniformity of substance and of diameter is chiefly secured by the skill of the workman, who, when he finds the metal running out too freely, repeats the operation of holding the cylinder vertically above

Fig. 162.

Fig. 161.

Fig. 160.

Fig. 159.

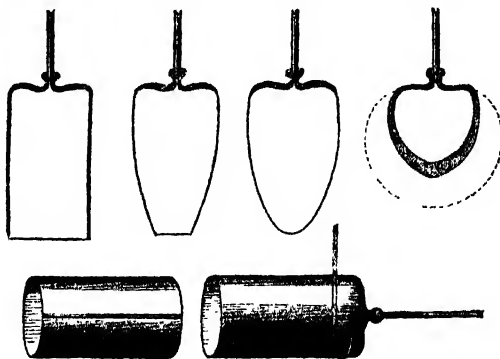


Fig. 164.

Fig. 163.

his head, still keeping it well filled with air. These operations are continued until the cylinder has reached the length required, as in Fig. 160.

The next stage of the process is opening the end of the cylinder. The thinner kinds of glass are all opened by submitting this part to the fire, and at the same time forcing in air through the pipe, and stopping up its aperture with the thumb. The air is expanded by the heat of the fire, and bursts open the cylinder at the end, this being the hottest and most yielding part. The thick and uneven margin of the aperture thus formed is trimmed with scissors, and

the cylinder now appears as in Fig. 161. The aperture is then widened out to the full diameter of the cylinder with the pucellas, and by turning the cylinder to and fro with the opening downwards, until by the centrifugal force, and its own gravity, the yielding glass assumes a uniform diameter with parallel sides, as shown in Fig. 162.

The ends of the thicker cylinders, if these were opened in the furnace in the manner above described, would be so thinned out that a considerable portion would be wasted. An extra mass of hot glass is therefore incorporated with such cylinders at the end, which thus becomes the hottest and weakest part, without applying them to the furnace, and the air forced in as before bursts them open. The opening is then enlarged by cutting round it with scissors.

The neck or cap is now removed by supporting the cylinder on a chevalet or wooden rest, and turning the upper part two or three times in the curve of a bent iron heated to redness, as shown in Fig. 163; a drop of water allowed to fall on the heated line produces fracture and separation of the cap. Or, the same may be done by wrapping round the end of the cylinder a thread of hot glass, removing the thread, and applying a piece of cold iron to any part which the thread covered.

The cylinder, as it now lies upon the chevalet, is little more in weight than two-thirds of the lump of glass which the gatherer collected on his pipe. The quantity left upon the pipe-nose, with that which formed the cap of the cylinder, are nearly equivalent in weight to one half the cylinder.

The next operation is to split it open along its length in the manner represented in Fig. 164. Till of late this was uniformly done by means of red-hot iron and water—a method which is still practised on the Continent; but in the English glass-works, it is now effected with greater certainty and regularity by a diamond, which, attached to a long handle, and guided by a wooden rule, is drawn along the inside length of the cylinder. In performing this operation, it is important to make the line pass through, or in the neighborhood of, some notable defect or group of defects, if such be present, for the line forms two edges of the future plate, and defects brought to the edges are of lessened injury to its value. An object to be avoided is the black mark which the cylinder sometimes receives from the charring of the wooden chevalet, on which, while hot, it rested in the glass-house. If the diamond passes, inside the cylinder, over the space occupied by this mark on the outside, the cylinder will fly to pieces. The reason of this, says Mr. CHANCE, is not difficult to understand. The chevalet prevented, by its non-conducting tendency, that portion of the glass with which it was in contact, from cooling equally with the rest, and the particles at that point remained in a state of tension. A careful blower will never place any large defect in his cylinder in contact with the chevalet, being aware of the probable result.

The use of the diamond in dividing plain surfaces of glass, dates from the sixteenth century; but its application to the splitting of cylinders which had not undergone the process of annealing, was introduced only about twenty years ago by M. CLAUDET, the distin-

guished photographer, then a glass manufacturer. Previously, all such cylinders were split by a red-hot iron, and, even now, all cylinders of flashed glass, that is, of ordinary sheet-glass covered inside with a skin of colored, are still split in the same fashion. On the Continent the diamond is gradually replacing the use of red-hot iron, though the latter is still the method more generally practised.

Having been split along its length, the cylinder is now ready for the flattener, who, having prepared it by a preliminary warming in the flue by which it is introduced into the *flattening-furnace*, passes it, by means of a croppie, or iron instrument bent at right angles, on to the *flattening-stone* or *spreading-plate*, which ought, of course, to be perfectly even and smooth, as the soft glass moulds itself to the surface upon which

it is flattened by heat. The sandstone of Godstone, in Surrey, has been found to answer well for this plate, which, however, is usually covered with a *lagre* or sheet of glass. Upon this lagre, *BB*—Fig. 165—the cylinder, lying with the split uppermost, is soon opened by the flame passing over it, and falls back into a wavy sheet.

The effect of the heat is assisted by spreading out the softened sheet, *A*, with an iron ruler, *C*, introduced through an aperture in the furnace. The flattener now applies another instrument, a *pulissoir*, or rod of iron,

C, Fig. 166, furnished at the end with a block of wood, *D*, and rubs down the waviness into a flat surface, often, upon a refractory piece, using considerable force.

Some cylinders are so distorted in the blowing that no rubbing can flatten them; but all, good, bad, and indifferent, pass through the same treatment. The flattening stone is now moved on wheels to a cooler portion of the furnace, and by the aid of the flattening fork, delivers its sheet to another stone, called the cooling stone. From this, when sufficiently stiff, it is again lifted, and then piled generally on its edge, in order to be annealed.

In 1842 the Messrs. CHANCE patented certain improvements, whereby, instead of at once removing the glass from the flattening to the annealing furnace, and lifting it to the cooling-bed while soft and liable to distortion, they flat and cool it by passing it through a succession of decreasing temperatures, so that it is not lifted until it becomes quite stiff and rigid. By this arrangement the workman can flatten the glass while the annealing is in progress, which could not be effected by the old method, because the temperature of the flattening kiln must be reduced with that of the annealing kiln, to which it is contiguous, thus leading to the successive heating and cooling of the kiln, and waste both of time and fuel. At Messrs. CHANCE's establishment the flattening and annealing kilns are two circular buildings communicating with each other, and shown in

Fig. 165.

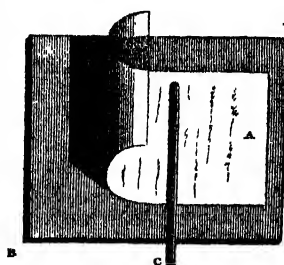


Fig. 166.

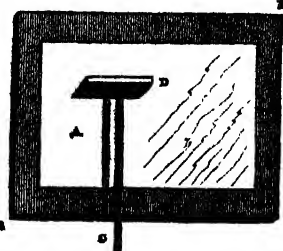
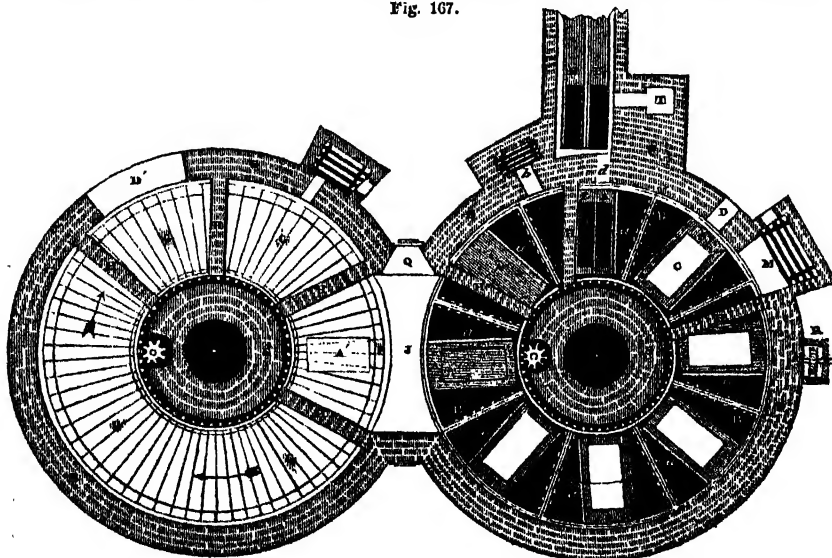


Fig. 167.



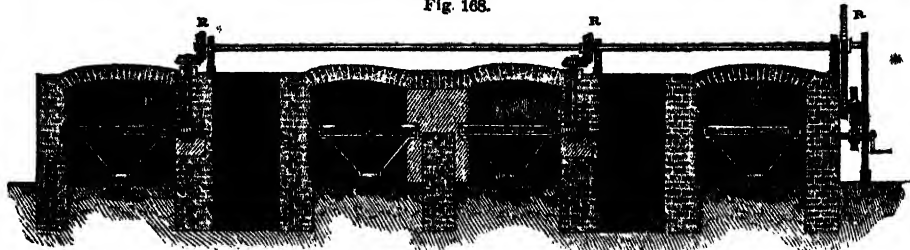
plan and elevation in Figs. 167 and 168. Each of the buildings consists of exterior and interior walls, *S*, the intervening space being a circular arched vault. In each vault is a cast-iron frame, moving on casters, and capable of being turned round by a winch on the outside, communicating with the shaft and bevil

wheels, *RR*—Fig. 168. The frame, *BB*, in the flattening kiln carries the flattening stones, *a*, and lagres, *A*, eight in number, and that in the annealing kiln a number of metallic wires, *G*, radiating towards the centre of the building, for supporting the sheets of glass. The flattening kiln is heated by the grate, *M*, and in order that the stones and

lagres, which will have cooled during the rotation, may be re-heated and arrive at the position, *r*, at a proper temperature, a second smaller grate is placed at *b*. If coke be used, a chimney at *t* will be required, but with

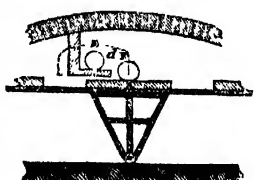
wood fuel it will not be needed. Partitions, *h*, are placed at certain intervals, to prevent the too rapid dissipation of the heat from those parts where it is most required, and to retard the entrance of cold air through

Fig. 168.



the openings in the external wall. At the bottom of the partitions are spaces to allow the frame, with the stones and glass or the wires and glass to pass below. The space, *j*, on which the glass is shifted from the lagres to the wires, is lighted by gas. The kiln is worked in the following manner:—The cylinder of glass is first placed in the position, *n*; then in that of *l*; thirdly, it is introduced through the external wall, *d*, and placed on a stone, *e*, suspended over the lagres; it is lastly placed in the position *r*, on the lagre beneath. To prevent the cylinder rolling off, the stones are provided with a

Fig. 169.



ledge. This part of the kiln is shown separately in Fig. 169. The frame *B* is then turned round till the cylinder of glass occupies the position *c*, opposite the working hole, *v*, through which it is then flattened in the ordinary way. From *c* the glass passes round in the direction shown by the arrow, till it arrives opposite *j*, when it is shifted to the position *A'* on the wires, by the flattener using his instrument through the opening, *q*; and after passing through the successive positions, arrives finally opposite *v'*, where it is drawn out fully annealed. Thus each sheet of glass, after having been flattened, remains on the stone during the time that other cylinders are being flattened, and before the sheet is lifted off the stone, it has passed through a gradually decreasing temperature, and has become rigid. The annealing is also carried on without lowering the temperature of the kilns by the movement of the frame, and the sheets, being isolated by the wires, become more quickly annealed.

* Mr. HARTLEY, of Sunderland, introduced two improvements in this operation. One consists in making part of the floor of the flattening kiln to consist of a movable stone, about ten inches in diameter, on which the cylinder is placed, and by causing the stone to revolve on its axis, the cylinder is gradually exposed on all sides to the action of the fire, thereby avoiding the objection to the previous plan, where one side of each cylinder became so much hotter than the other. His other improvement consists in making holes, about the eighth of an inch in diameter, all over the flattening-stone. When the sheets of glass are to be polished, the absolute smoothness of the original surface is not

so much an object as to have them perfectly flat, and the air which lies between the common flattening-stone and the cylinder or spread sheet renders this difficult to accomplish; but by Mr. HARTLEY'S process the difficulty is overcome.

One of the most recent improvements is that of Mr. FARTHING, in which the kiln is heated by means of flues arranged under the floor, around the walls, and over the arch. By this means all deposit of dust or hard particles from the fuel on the surface of the glass is avoided, and any cheap kind of fuel may be employed.

To return to the flattened sheets. When annealed, they are drawn from the kiln, and carried to the warehouse, where they undergo examination. Being blown by a less complex process than crown, sheet-glass is liable, in the glass-house, to a less number of defects, but the subsequent process of flattening, notwithstanding the improvements above mentioned, often makes up the deficiency; and the manner in which a sheet, spared by one process, is disfigured by another, is described by Mr. CHANCE as sometimes curiously provoking. Standing upon the table of the *assorter*, he remarks, your eye lights upon a piece which, blown under an evil star, has imbibed in the glass-house every possible defect. The founder, skimmer, gatherer, and blower have all stamped their brand upon it. It is seedy—the vesicles, which were in the crown tables rounded by the rotary motion of the piece, are here elongated by the extension of the cylinder; it is stony, disfigured with stony droppings from the furnace; stringy, thin threads of glass meandering over its surface; *ambitty*, covered with stony speckles, symptoms of incipient devitrification; conspicuous with gatherers' blisters and blisters from the pipe—badly gathered; badly blown—thin here, thick there, and grooved with a row of scratches; and on this abortion the flattener chances to have exerted his most exquisite skill; it has passed through his hands unscathed, flat as a polished mirror, yet, from its previous defects, is entirely worthless. Next comes before you a piece whose beginning was miraculous—no seed, no blisters; it prospered under the hands of the gatherer and blower, and left the glass-house a perfect cylinder. But the cropple of the flattener marked it; the fire scalded it; dust fell upon the lagre and dirtied it; scraps from the edges of the preceding cylinder stayed upon the lagre, and stuck to it; the stone scratched it; and the heat of the annealing chamber

bent it. Such are the difficulties to which every cylinder is subject—those of the glass-house, and those of the flattening kiln. Not all, however, are such as these; there are good as well as bad, but the good are generally in the minority.

The qualities range thus—best, seconds, thirds, fourths, and H, the latter standing for horticultural, and including all coarse glass, such as may be applied to horticultural purposes. The difficulty of escape from defects renders the best quality, as in crown-glass, three times as costly as the common. The expense of production to the manufacturer is in each case the same; the materials, the labor, the fuel, the same for each. Success, therefore, clearly hinges on the proportion of good glass which a manufacturer can obtain. The six qualities of sheet-glass may each consist of six different thicknesses, forming thus, in all, thirty-six varieties.

When this manufacture was new in England, the size usually blown was thirty-six inches long, and twenty wide. The usual size now is forty-seven inches long by thirty-two wide, and cylinders are occasionally blown seventy-seven inches long; but large sizes and heavy weights are accomplished only by workmen of the first class. A sheet of this latter size, containing twenty-one ounces to the foot, would require for its formation a lump of glass upon the gatherer's pipe, of no less than thirty-eight pounds weight.

The size which sheet-glass can thus reach is obviously a great advantage, and adapts it to many purposes from which the limited dimensions of crown are excluded. It was this glass that covered the Great Exhibition in 1851. A cylinder was blown to cut, as the phrase is, forty-nine inches by thirty; this was subdivided into three panes of forty-nine inches by ten. About three hundred thousand of these, extending over a million square feet, and weighing upwards of four hundred tons, were the work of a few weeks, and this without absorbing or interrupting the ordinary produce of the manufacturer. The energy of the glaziers was equal to their task; eighteen thousand three hundred and ninety-two panes were fixed in the roof in one week by eighty men, one hundred and eight panes being accomplished by one man in a single day. It was the house of CHANCE and Company which executed the large order for the Exhibition, without materially affecting their power of executing their general orders, a feat almost unparalleled in the history of the manufactures of this country.

But sheet-glass has its faults as well as its virtues; it is devoid of that brilliancy of surface for which crown is so remarkable. It is subject, also, to undulations on the surface, the precise origin of which it is difficult to explain. Mr. SHAW, in his admirable lecture on the glass manufacture, as illustrated by the Great Exhibition, speaking of this defect, says—When the divided cylinder is softened by heat, and either allowed to flatten by its own weight, or flattened by the workman, the concave interior of the cylinder has to expand, and the convex exterior to contract, as the curved surface becomes plane. He adds, were this contraction and expansion to take place uniformly throughout the glass, the undulation in question would not occur, but since

one part invariably yields somewhat more readily than another, perfect flatness cannot be attained.

It is, however, more probable, in Mr. H. CHANCE's opinion, that this undulation is produced in the operation of blowing, and is due to the double movement of the particles of glass which accompanies the formation of every cylinder, the one movement being parallel to the axis of the cylinder, and the other in planes at right angles to that axis.

Grinding and Polishing Sheet-Glass—A further development of the sheet-glass manufacture in England is the process of polishing and grinding this glass by machinery, whereby a new branch of manufacture has been established, which has furnished glass peculiarly applicable for purposes for which none previously existed. This improvement, which is the work of Mr. JAMES CHANCE, is characterized by M. CLAUDET as one of the greatest improvements which has ever been introduced in the manufacture of window-glass, as it has produced, at a cheap price, an article equal in effect to plate-glass, and by which houses can now be glazed with a glass that does not distort external objects, while, at the same time, when viewed from the outside, it has all the polish and fine appearance of plate-glass. To explain the merits of this invention, it must be recollected that the sheet-glass has the polish of its surface much injured by the mode of its production, and that a still greater defect arises from the inside and outside of the cylinder not being of the same length, so that when developed by the flattening operation either the one surface must contract or the other expand; and the result is a kind of undulating or wavy appearance called *cockles*. These cockles reflect and refract light in various directions, and the objects seen through the glass are necessarily distorted.

Several attempts, continues M. CLAUDET, were made in France and Germany to grind and polish this glass, in order to destroy these inequalities and imperfections. For this purpose sheet-glass had to be made considerably thicker, owing to its never being perfectly flat throughout its length and width, so that one corner or another, and even several points on the surface, were liable to be completely worn out before the end of the operation.

Mr. JAMES CHANCE conceived the ingenious idea of laying every sheet of glass intended to be ground and polished, upon a flat surface covered with a damp piece of soft leather. The sheet adhering completely to the leather after having been pressed against, produces, in fact, a vacuum, so that by the pressure of the atmosphere the whole sheet is maintained in a flat position. Two sheets having been placed in this manner, each on the retaining or sucking surface, they are turned one against the other in a horizontal position, sand and water being constantly supplied between them; and by means of the most ingenious machinery, the two surfaces rapidly rub one against the other in all directions, and are ground at the same time by the sand. When the grinding has been performed on one surface, the sheets are turned to have the other surface ground in the same manner.

The sheet being ground while it is kept perfectly flat, it is not necessary to wear out more than a thin

layer of the whole surface. Of course, after the operation, the sheet of its own elasticity resumes its former shape more or less curved, but the whole surface of both sides has a polish as perfect as plate-glass, and this is the desired condition for glazing purposes. Although the glass could not make perfect mirrors of a large size, on account of the slight curve arising from the flattening operation, still it may be usefully employed for small looking-glasses. M. CLAUDET states that this glass has all the perfection and qualities required for taking pictures by the collodion process, and for framing all photographic and other pictures, for which last purpose it is even preferable to cast plate-glass on account of its lightness.

Mr. JAMES CHANCE's invention is, therefore, one of the most important improvements in the manufacture of window-glass during the present century; and to him is due the cheap but beautiful glass now so generally used in glazing ordinary dwelling-houses—an article quite equal in effect to the expensive plate-glass which was formerly seen only in the windows of palaces and aristocratic mansions.

IV. PLATE-GLASS.—DODD justly remarks that a better name than *plate-glass* would be *cast-glass*, since the former is vague in its acceptation, and might be applied to any kind of glass in sheets, whereas the latter expresses the mode of manufacture of this beautiful article, which is formed by being *cast* or *founded* upon a smooth table while in a liquid state, and is totally independent of the process of blowing. It is not generally known, however, that originally all plate-glass was made by blowing; and that in this country it was not till 1773 that the British Plate-Glass Company first began to make plate-glass by casting, although this process had been in use in France for nearly a century. The method of blowing plate-glass was very similar in principle to that of sheet-glass, differing only in some mechanical contrivances to assist the workmen in handling so much heavier a piece. The plates formed by this method, however, were much smaller than can be executed by the casting process, which sometimes exceed ten feet in length, and are about half an inch thick. Plates have been cast as much as fourteen feet long by eight or ten feet in width, and some of enormous dimensions were shown at the Great Exhibition.

The principal consumption of plate-glass is for mirrors, the manufacture of which dates from the earliest introduction of glass-works into Europe. Mirror-glasses were for many years the object of an important commerce to Venice, the only city which could produce them. The manufactory, which was situated on the island of Murano, produced, however, only sheets prepared by blowing, and this was the process imported into France in 1665, along with the art of covering plates of glass with tinfoil, which had long been exclusively possessed by the Venetians. The largest mirror-glasses which could be made in this manner were about three feet in the side, and they were liable to the air-bubbles, knots, and striæ so frequent in common window-glass. All these disadvantages disappeared with the invention of the casting process which is now in use. ABRAHAM THEVART devised this bold me-

thod, as DUMAS terms it, and put it in practice at Paris in 1685. It was the same artist who founded in 1691 the celebrated manufactory of Saint Gobain in Picardy, which remained so long without a rival, and where perhaps the best plate-glasses are still made, though two or three other manufactories have been established on a very large scale, which renders the mirror-glass manufacture a very important object for France. In this country, as in France, the business is confined to a very few large establishments.

Composition of Plate-Glass.—This beautiful variety of glass is similar in composition to crown and sheet glass, the only essential bases being lime and soda; but in plate-glass the soda is introduced in somewhat larger proportion. So far as regards the purity of the tint, it would be attended with advantage to substitute potassa for the soda; plate-glasses would thus be freed from the greenish or bluish shade which they sometimes present, and, in this case, one might increase the proportion of lime, which is kept comparatively low in plate-glass to avoid devitrification. But soda is preferred to potassa for this description of glass, because it imparts a higher degree of fluidity, and because the impurities which it contains are more readily dissipated by the heat; so that the use of soda, though objectionable as tending to color the glass, facilitates both the fining and casting—two most important advantages in the manufacture. Subjoined is the analysis of a plate-glass by DUMAS:—

	Centesimally.	Oxygen.
Silica,	75.9	= 39.4
Alumina,	2.8	= 1.3
Lime,	3.8	= 1.0
Soda,	17.5	= 4.4
	100.0	= 6.7

From this analysis it appears that the quantity of oxygen of the silica is about six times that of the aggregate oxygen of the bases. It will be seen, also, that this glass differs considerably from window-glass in the proportions; in the latter, for each equivalent of soda, there is always at least half an equivalent of lime, whereas, in plate-glass, for one equivalent of soda, there is only one-fourth of an equivalent of lime. In window-glass, putting the alumina and lime together, the oxygen of these earthy bases always exceeds the oxygen of the soda; in plate-glass the oxygen of the lime and the alumina constitutes scarcely the half of that of the soda. All these circumstances have the effect of rendering the plate-glass more fusible, more readily altered, and less hard than window-glass; but it is also less brittle, and less liable to be devitrified.

The preceding analysis is elementary and theoretical; the subjoined practical recipes are given in KNAPP'S *Technology*:—

Composition used at St Gobain.	Composition according to Bastenaire.
100 pounds pure sand from Senlis.	100 pounds white sand.
35 pounds pure salts of soda.	60 pounds salts of soda.
5 pounds lime, crumbled.	13 pounds carbonate of lime.
100 pounds broken glass.	100 pounds broken glass.
Decoloring matters.	1 pound peroxide manganese.
	0.5 pounds smalt.

The following proportions, which have been used in England, are said to produce a superior quality of plate-glass:—

	Parts.
Lynn sand, well washed and dried,.....	720
Alkaline salt, containing forty per cent. of soda,.....	450
Lime, slaked and sifted,.....	80
Nitre,.....	25
Broken plate-glass,.....	425

These quantities produce one pot of *metal*, which yields one thousand two hundred pounds of glass.

The object for which plate-glass is chiefly manufactured requires in the materials the highest degree of purification, and the utmost care in the fabrication. A good mirror should reflect an image in its true and natural shape, and no distortion must occur, which invariably happens if lumps or waves in the glass unequally refract the light or produce irregular reflection. Moreover, the light must pass through the thickness of the glass before it is reflected from the metallic surface at the back; and as the thickness of the plates must correspond with their lateral dimensions, which are often considerable, it is evident that transparency and absence of color are points of great importance. It is true that in the last century this was a disputed question. MONTANEY advanced that the black color was preferable to all others for mirrors, and his theory appeared so plausible as to require a formal refutation on the part of ALLUT. It is evident that, unless the light were assumed to be reflected at the first surface, this theory is quite untenable; and even assuming the reflection to take place at the first surface, it would be necessary to give the glass, not only a black color, but a complete opacity, similar to that of the metals themselves, of which mirrors were anciently made; but this absolute opacity, in the case of glass, would be very difficult, if not impossible, to attain.

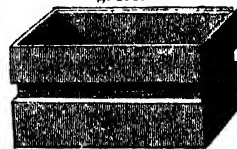
In the present day the object aimed at, by universal agreement, is to give the most perfect transparency to mirrors, and to destroy the slightest traces of coloration. With this view, not only must the metal or melted glass be thoroughly fused, but the original materials must be selected with very great care. The sands which enter into the composition should be very white and fine. In default of suitable sand, soft sandstone, white and well pulverized, is used. Flint and quartz, calcined and reduced to powder, are excellent materials for the purpose. Particular care must be taken in the choice and treatment of the soda, to avoid, as far as possible, the green tint which is peculiar to glass formed with this alkali, and which the thickness of the plate-glass betrays. It might be possible to counteract this evil to a certain extent by a perfect fining or purification of the soda, and by replacing part of it with potassa, to the amount of about one-fifth. If plate-glass were formed with potassa alone, instead of soda, it is to be feared that a glass necessarily so rich in alkali, would be hygrometrical, and would partake too much of the nature of soluble glass. Even the small proportion of potassa which, in the shape of nitre, usually enters into the composition of French plate-glass is found to give it a dampness, so that when two of these are kept together for any length of time, they can scarcely be separated. Mr. VARLEY stated at a meeting of the Society of Arts, that he was once shown some very large glasses by a London manufacturer, which were beautifully clear, but appeared

to be covered with steam, and this, when wiped off, appeared again. The manufacturer had applied to Professor FARADAY in hopes of learning how to cure this imperfection. On examining these glasses with a magnifier, the apparent steam was found to consist of very minute but long crystals, which shape indicated nitre, showing that so much potassa was used in the manufacture of the glass that it exuded. Now, repeated washings, which, with eight or ten feet glasses, is a serious labor, might much lessen the exudable matter; but the glass would thus become porous all over, and its power of transmitting or reflecting light would be diminished. What was still worse was, that such glass could never be wiped so as to remain clean, for the wiping filled up the pores with what should have been quite removed. This began again to exude in minute gummy dots, which continued to enlarge, and on again wiping, smeared the surface, rendering it difficult to clean. Soda is prone to dry and lose its water of crystallization; potassa, on the contrary, attracts moisture, and becomes liquid. Hence it would seem that soda must make the more durable glass, besides fulfilling the important conditions of rendering the vitreous composition more fusible and more easy to fine. The latter advantage arises from the fact, that the gall or sandiver of the soda-glass, consisting of sulphate of soda and chloride of sodium, is more volatile than potassa-gall, and is hence more readily got rid of from the open pots in which the glass is fused.

Melting and Fining.—Two sizes of pots are used in the manufacture of plate-glass—the larger for melting the vitreous mixture, and for keeping it long in a state of fusion—the smaller for receiving a portion of the glass to be fined and cast. The latter are termed cisterns, or in France *cuvettes*. The English pots and cisterns are of the same form as the pots used in the manufacture of crown-glass; and this is also the form of the French pot—Fig. 141; but in France the cistern or *cuvette* is formed square or rectangular—as shown in Fig. 170—and three pots contain the material for six small *cuvettes*, or for three large ones. These last are employed for mirrors of large dimensions—for example, of one hundred inches and upward. Latterly, furnaces have been constructed for six pots and twelve *cuvettes*, eight small and four large ones. The small ones have the form of a perfect square, the large ones of an oblong rectangle. About the middle of the depth of the *cuvette*, *AA*, a groove or indentation, *n*, is formed, whereby the vessel is grasped with the tongs.

The ingredients for plate-glass were formerly fritted before melting; but this preliminary process is now dispensed with, the mixture being composed of such pure materials that it can be placed cold in the pot in three successive charges. The time necessary for the fusion and the fining is in France divided equally between the pots and the *cuvettes*. The material is left sixteen hours in each, and, at the end of these thirty-two hours, it is fit to be cast. During the melting of the mixture in the pots, the *cuvettes*

Fig. 170.



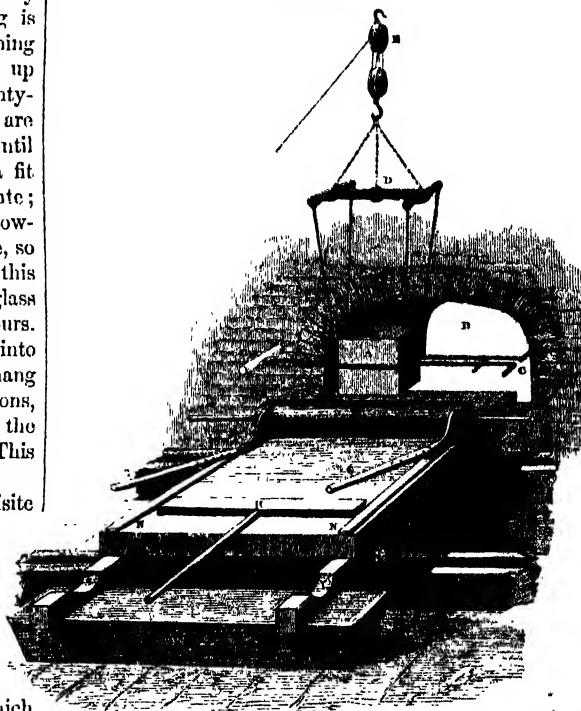
are placed empty in the furnace; but as soon as the whole charge is in a state of fusion, the cuvettes are removed by means of tongs, and cleansed from all impurity, and from the residual glass of the last operation by a scraper. They are then replaced in the furnace, and after a few moments' heating, the ladling or transferring operation commences. The surface of the metal in the pots is skimmed, and the liquid glass is transferred into the adjacent cuvette with a copper ladle, care being taken not to disturb any grains of sand or lumps that may have settled down at the bottom of the pot. Thus, as KNAPP remarks, at the very commencement a kind of double purification is effected—the infusible portion is left untouched, and the glass is well mixed by the agitation of ladling. This transferring process, which is termed in France *tréjetage*, requires two workmen, one after the other; each draws out the glass three times—whence the word *tréjeter*, to throw or cast thrice—and then plunges his ladle into cold water. The furnace is then shut, and the cuvettes are left to themselves, for the glass to fuse—that is to say, that the bubbles excited in the mass by the *tréjetage* may be disengaged, and the excess of soda be entirely volatilized. It has been stated that the melting is generally accomplished in sixteen hours; but the fining which succeeds the ladling process must be kept up quite as long, and extends indeed sometimes to twenty-four or even forty-eight hours before the bubbles are dispersed and no more alkali is volatilized, or until specimens of the glass exhibit in every respect a fit state for casting. This is not exactly a liquid state; but after the perfect melting has taken place, the glowing mass is allowed to lower its temperature a little, so as to acquire a slight degree of viscosity. With this view the fire is allowed to decline, and the glass acquires the proper consistency in three or four hours. To make sure of this, the end of a rod is dipped into the cuvette; the portion taken up is allowed to hang down, and by the form it assumes and other indications, the workman readily judges whether it has acquired the necessary consistence and is free from bubbles. This is termed *drawing the glass*.

Casting.—While the glass is acquiring the requisite consistence, attention must be given to heat the annealing furnaces, as well as the casting-slab or metal plate which is to receive the liquid glass. This table was formerly made of bronze; but the liability of this metal to crack induced the British Plate Company to try a plate of cast-iron, which was found to be quite successful, and even the large bronze slab at St. Gobain, which weighed fifty thousand pounds, and cost one hundred thousand francs, or £4000, has been discarded, and replaced by one of iron. The table, *TT*—Fig. 171—must be of longer dimensions than the largest plate; it varies from ten to twenty feet in length, with corresponding breadth, and is six to seven inches in thickness; it rests on a strong wooden frame or truck, *MM*, movable on casters, and sometimes running on a railway, along which it is wheeled from one annealing oven to another, since it is necessary that the table should be placed close to the oven or arch, *B*, into which the plate is to be removed for annealing after being cast.

With this view the height of the slab or table is made exactly on a level with the floor of the arch. Its upper surface is flat and polished, to mould the lower surface of the mirror; and, before the casting, it is heated by hot coals spread over it, and then wiped perfectly clean.

The annealing-ovens being heated to a brown-red, the casting-slab brought to a suitable temperature, and the metal or melted glass thickened to the requisite point for flowing readily and equably, the aperture into the cuvettes which are to be taken out is then opened; two workmen introduce tongs into the furnace, and grasp the cuvette by the groove shown in Fig. 170, while a third slides a large pincer under it. When this instrument is pushed well under the bottom of the cuvette, the workman draws it towards him, aided by the others with their tongs, which are supported on rollers. In this manner the cuvette is drawn to the mouth of the opening, where it is raised by a crane, placed upon a truck or low carriage, and removed to the casting-table. The melted glass being skimmed, the cuvette, *A*—Fig. 171—is then drawn up to a sufficient height

Fig. 171.



by the tackle, *DE*, and suspended above the upper end of the casting-table, where it is tilted over by means of the tongs, *CC*, and the metal is poured out on the table. The appearance presented by the molten sheet is now exceedingly splendid. The building being very dark within, the glowing liquid throws a strong light on the faces and persons of the workmen. In the meantime, the glass is prevented from running over the sides by ribs or rims of copper, *NN*, which are exactly equal in height to the intended thickness of the plate of glass; and when the cuvette has been emptied of its contents, a

massive hollow copper cylinder, F, three feet in diameter, and resting at each end on the side ribs, is set in motion. This cylinder, which weighs several hundred-weights, is moved by means of the handles which form a prolongation of the axis, and spreads the glass out into a sheet of uniform breadth and thickness. It would, however, overflow the sides, if this were not prevented by the workmen applying the iron pieces, G G, which form a dam at the sides, and precede the course of the rollers. Lastly, to prevent any impurity from contaminating the glass, a workman draws the washer, H, covered with cloth, immediately in front of the advancing sheet of fluid glass; the excess of glass pours over the front edge of the slab into a trough, K, filled with water, and finally the roller passes off and is received in the grooves, I I. A beautiful play of brilliant colors, comprising every imaginable tint, is exhibited by the glass immediately after the roller has passed over it; caused, probably, by a temporary oxidation of the surface.

Whilst the cuvette is carried back to the furnace to receive a fresh charge of glass, the two ribs are removed, and any blisters or seams or redundancy which may exist at the two sides of the plate are broken off; a thick flange of the still soft glass is then turned up at the end, T T, and a rake-shaped iron is applied to it, by means of which the plate is thrust forward into the annealing oven, N, where it rests upon sand. As the plate is not perfectly rigid when this is done, the force which must be exerted to push it over the floor of the kiln often produces considerable undulations on the upper surface, which subsequently disappear under the polishing.

While the introduction of the plate into the annealing arch is being proceeded with, other workmen are engaged in taking from the firing furnace another cuvette, which arrives at the casting-table at the moment when the preceding plate has just been introduced into the annealing oven. After filling the oven, all the openings are carefully stopped up with iron plates and clay mixed with sand. At the end of twenty hours, some of the pieces of iron are taken away; an hour or two afterwards more are removed; as the oven cools, more and more are taken away, and at last the whole of the clay and plates of iron which stopped the apertures are removed. When the hand can be placed on the glass plates without feeling much heat, they may be taken out of the oven. Such, at least, is DUMAS' account of the French method. But in this country the plates are allowed to remain in the oven, resting in a horizontal position, from five to ten days.

It has been stated that the temperature of the annealing kiln, when the plates are introduced, should be a dull red. If the kiln were too hot the plates would enter into a state of semi-fusion, and would get out of shape, or at least would adhere to the floor of the kiln, so that they could not be detached without breaking. On the other hand, if the kiln were too cold, the plates would be badly annealed, and might fly to pieces in the act of being taken out of the oven, or afterwards. The slightest change of temperature is sufficient to split into pieces plates which have been badly annealed. They break also when one proceeds to cut off the jagged

edge with a diamond. It almost always happens that, in plate-glasses badly annealed, the separation does not occur at the place where the incision has been made.

The annealing ovens, termed in France *carguaises*, are very large, and have several fire-places. The bed or floor is made of bricks, presenting in its whole extent a perfectly level surface. Sand must be sprinkled over the bed, that the plates may slide freely upon it, and encounter no impediment in shrinking or contracting.

Squaring, Grinding, and Polishing.—After being withdrawn from the annealing oven, the plates have to undergo the operations of squaring, grinding, and polishing. As taken from the oven, they are about half an inch thick, and present an irregular mottled appearance, roughened on the lower surface by the sand on which they have rested, and smoother, but not flat on the upper surface. The first process is that of squaring, or cutting them into their useful dimensions; for which purpose they are carefully examined, and the workmen endeavour, notwithstanding the imperfect transparency of the glass, to select those which appear to be free from defects, to be reserved for large plates, while such as show imperfections that cannot be removed by grinding, are picked out to be cut into smaller plates, transposing the faulty parts to the sides. The squaring is performed by passing a rough diamond along the surface of the glass, guided by a square rule; the diamond cuts to a certain depth into the substance, when, by gently striking the glass with a small hammer, underneath the part which is cut, the piece comes away; and the roughnesses of the edge then left are removed by pincers.

The plates having been squared, next undergo the processes of grinding and polishing. In these operations two plates are employed, one of larger dimensions, and one three or four times smaller, which are made to rub against each other. This was formerly done by hand, but is now almost entirely performed by machinery. The lower and larger plate is embedded in plaster of Paris, in a perfectly horizontal position, upon a table about two feet high, which is termed the *grinding bench*; the smaller plate is cemented upon the lower face of a swing table, made heavy by weights, and caused to traverse over the lower plate in such a way, that by a combination of a rotatory and oscillating motion, the relative position of the two plates is constantly changed. In adjusting the plates, a rough or rolled surface of the one is opposed to the comparatively smooth or casting-plate surface of the other, and the material employed to grind the surfaces is thrown upon the lower plate from time to time. River sand and water were formerly used for this purpose, but ground flint of different sizes is now substituted, as answering the purpose better. The machinery is set in motion by a steam-engine, and this process is continued until the ground plates exhibit a perfectly horizontal and even, though still unpolished surface. When one side of each plate has been sufficiently ground, it is loosened from the frame and turned over, so as to present the other surface to be ground in the same manner. Some degree of pressure is employed by loading the upper plate with weights, as the grinding of each side approaches to completion. The

process thus described used formerly to last three days, but the time is now much abridged. The greatest attention is required to complete the operation, with the surfaces perfectly level and parallel, for which end a rule and plumb-line are employed.

By means of this grinding, the plates are made level, but are still too rough to receive a polish. To fit them for this, they are now ground with emery powder of increasing degrees of fineness. When the plates become sufficiently smooth for this operation, there is a tendency to cohesion between the surfaces, which produces so much friction that when the work is done by machinery one surface will frequently tear the glass from the other. Hence hand labor has been generally employed in this part of the process. The lower plate is placed upon a stone bench covered with wet canvas, which holds it firmly in its place; the surface is sprinkled with emery and water, and a small plate, moved by the hand, is used as a runner or grinder. Women are generally employed in this operation, and are said to perform the work better than men, on account of their superior delicacy of touch, which enables them to use precisely the degree of force required, and readily to detect and remove gritty particles among the emery. Young girls are employed on small plates. About three sizes of emery are used, the different qualities being previously separated and assorted by suspension in water; and between every size the plates, canvas, bench, and hands are thoroughly washed. After the application of the last or finest emery, the plate has become quite smooth and partly polished. To dispense with the necessity of manual labor in this operation, Mr. BLAKE, of the Thames Plate-Glass Works, has recently introduced a machine which imitates the motions of the arms of the persons employed in smoothing, and works admirably.

The glass, although now perfectly even, appears opaque and deadened on the surface, and still requires the final polishing. To effect this, a piece of wood is covered with numerous folds of woollen cloth, having carded wool interposed between each two layers, so that the whole forms a tolerably hard but elastic cushion, which is fitted with a handle. The plate is embedded in plaster, as already described, and the cushion, being wetted, is covered with Venetian pink, which contains a small portion of oxide of iron, mixed with earthy matter, and is moved backwards and forwards on the surface of the plate, with considerable pressure. This rubbing is now generally performed by machinery, as hand-polishing is tedious, and is apt to produce a wavy appearance; hence machine-polished glass is to be preferred.

In 1856, a patent—communicated by ALBERT BROUGHTON, ALEXANDER LINDSAY, and JOHN RUTHVEN PLATT, all of New York—was taken by WILLIAM EDWARD NEWTON, of the Patent Office, Chancery Lane, London, for an improved method of polishing the surface of glass, stone, metal, or other materials capable of being polished by friction. The distinguishing principle of this method consists in grinding and polishing the flat surfaces by means of a rotating plane of glass, metal, stone, or other suitable material, the substances of which the surfaces are to be ground or polished being held in a frame in such a man-

ner, that the friction, exerted by the rotating plane upon the surfaces of the substances under operation, will cause them to rotate with a slower motion upon their own centres. The form adopted as most convenient for the grinding and polishing surface is circular; it therefore generally consists of the upper surface of a circular table or wheel, which may be of cast-iron, and is secured firmly at the upper end of a vertical shaft, which is supported in suitable bearings in a strong framing of timber or iron. The upper end of the shaft is not allowed to stand above the table, and therefore the article to be polished will be allowed to pass over its centre. Rotary motion is communicated to this circular table by means of suitable gearing. The apparatus for holding the plate of glass to be ground and polished consists of a plate or frame of metal or wood, having a rim all round the lower side, within which the glass is received in a bed of plaster of Paris. This plate or frame is connected with a perpendicular spindle which is capable of being moved nearer to or further from the centre of the rotating circular table. The grinding and polishing operation is effected with the aid of sand, or any common polishing material. To commence the operation, the plate of glass, having been secured in its bed or frame, is placed on the rotating circular table, and the holding plate or frame is connected with the long lever by means of its spindle. Rotary motion is now given to the circular table, and when the sand or grinding material is properly distributed, the friction produced on that part of the plate of glass which is at any time on that side of the spindle of the holding frame which is furthest from the centre of the table, being greater than that on the part which is at the same time on that side of the spindle nearest the centre of the table, causes the plate to rotate in the same direction as the latter. The sand or grinding material, when a fresh supply is applied, will always distribute itself evenly after a very few revolutions. The grinding may be regulated by a screw and nuts on the spindle of the holding frame, so as to produce a pressure on the plate, additional to what is produced by its own weight, and the weight of the plate or frame and other parts of the holding apparatus, or to take off some of that pressure. The patentee alleges that, by producing the rotary motion of the glass to be ground and polished, by means of the friction of the grinding or polishing surface, an evenness and smoothness and freedom from scratches are obtained, that cannot be produced when the rotary motion is positive, or produced by gearing, as in other polishing machines. The reasons assigned for this are as follow:—In the former case, the grinding or polishing surface and the surface to be ground or polished undergo an infinite transposition, while in the latter, they are frequently in precisely the same relative positions; again, when the motion is produced by friction, it is found to be steady and free from the tremor which is produced when an independent and positive motion is given.

The Editor is informed by Mr. FINCHAM, the active and intelligent manager of the British Plate-Glass Works, that the preceding process acts admirably, and is sure to supersede all those hitherto in vogue. It is daily working under Mr. FINCHAM's superintendence.

Mr. BESSEMER some years ago proposed a new method applicable to the whole process of casting, grinding, and polishing plate-glass. Dispensing with the use of cuvettes, he pours the melted glass directly from the pots between two rollers, placed at a certain distance apart, and kept cool by a current of water passing through them. This insures a uniform thickness in the glass. The furnace employed by Mr. BESSEMER is a reverberatory with a low arch, and the pot, which is of very large dimensions, is set upon a movable siege composed of masses of firestone firmly cemented together. The pot and siege run upon four wheels, by means of which they are readily moved out of the furnace, to empty the contents of the pot between the two *forming* rollers already alluded to, and, after passing between these, the glass is received between two *finishing* rollers placed closer together, and moving with accelerated speed, so that, on emerging from the latter, the glass appears smooth and flat, though wanting in polish. The plate now slides down a curved surface upon a flat table, and, when sufficiently cooled to become rigid, it is transferred to the annealing kiln, which is heated by a current of hot air obtained from a chamber situated between the furnace where the glass is melted and the chimney. A saving of fuel is thus effected, the heat is more easily regulated, and the articles to be annealed are not subject to injury from the dust and products of combustion of the fuel. The polishing, according to BESSEMER'S method, is performed by laying the plate of glass upon a slab of slate placed perfectly horizontal upon a bed of brick-work, and causing an endless belt of gutta percha, covered with felt and polishing material, to pass rapidly over the surface of the glass in contact therewith, and to traverse at the same time slowly across the plate by a lateral motion at right angles to the line in which the belt moves over its drums. The belt is of the same length as the sheet to be polished, and is pressed upon the entire surface of the glass by a number of small rollers. The continuous action of the strap in one direction renders it unnecessary to cement the glass to the table, which is effectually prevented from shifting its position by a raised rib or stop let into one end of the table.

By the grinding and polishing, the plates are reduced in thickness as much as one-third, and in some cases one-half. If any radical defects exist in the glass, these are only heightened by the polishing, and hence a second and more careful examination and selection of the plates is now made. In fact, in every stage of the manufacture, the experience of the workman is called for, to determine whether any and what imperfections appear, and how they are to be removed; and as, on the one hand, no manufactured article would betray the existence of defects more readily than a large sheet of plate-glass, so, on the other hand, the most sedulous attention is paid to the detection of such defects when they appear in the course of the manufacture. Those which are still found defective after the polishing, are cut up into smaller plates, and polished again, while the perfect ones, when destined for mirrors, are subjected to the final process now to be described.

Silvering of Mirrors.—This designation is a misnomer, there being no silver used in the common method of performing the operation; but a compound of tinfoil and mercury, or quicksilver, whence probably the mis-appellation. The operation is commenced by spreading a sheet of tinfoil, which must be of somewhat larger dimensions than the plate to be covered, upon a flat stone or slate slab, termed the *silvering table*, and brushing mercury over it. When the surface of the tinfoil is uniformly covered, more mercury is added till it covers the metallic sheet to the depth of one-sixth or one-fourth of an inch. A brilliant surface is then produced upon the fluid metal, by skimming aside the grey coating of oxide with a wooden rod. The plate of glass is now introduced by pushing it forward horizontally from one side of the table, with the longest edge foremost, and so that this edge always dips below the surface of the mercury. By this means dust and air are totally excluded; whereas, if the plate were let down perpendicularly upon the mercury, more or less of both would certainly be enclosed between the glass and the amalgam. On the contrary, by sliding it forward in the manner described under the surface of the mercury, the pure metal alone is brought into contact with the glass. To get rid of the excess of quicksilver, the plate or mirror is loaded with weights, and the table is inclined at an angle of ten or twelve degrees, when most of the uncombined mercury flows away. The last portions are removed by placing the plate in an upright position, and in the course of three or four weeks a dry permanent coating of tin amalgam is left on the glass.

A great disadvantage attending this operation is the serious detriment to the health of the workmen from the vapor of the mercury; another objection is the very considerable time required to complete the work; and, lastly, the process is subject to frequent failure from different causes: the plates often break under the pressure of the weights, and, when set on edge, drops of mercury sometimes trickle down, and carry the amalgam with them, producing curved streaks, technically termed *worms*, so that it becomes necessary to re-silver the whole mirror. The amalgam, also, is liable to spoil by crystallization, and is easily injured by carriage. A process proposed by DRAYTON, and tested by FARADAY and WARRINGTON, is free from these defects. It consists in employing a *silvering fluid*, obtained by mixing ammonia with nitrate of silver, filtering the mixture, and adding to it an alcoholic solution of oil of cassia. The proportions are one ounce of nitrate of silver, three ounces of alcohol, of the strength of 87 per cent., and twenty to thirty drops of cassia. This fluid has the property of depositing *bright metallic silver* on the addition of what is termed the *reducing liquid*, consisting of a solution of one part oil of cloves in three parts alcohol. The term *silvering* is, therefore, strictly applicable to this process, which is performed by surrounding the plate of glass, after being perfectly cleaned, with a rim of putty, and pouring upon it a layer of silvering fluid to the depth of one or two lines. The oil of cloves solution is then added, and, more or less rapidly, in proportion to the quantity of this solution

employed, a film of brilliant metallic silver is deposited, and attaches itself firmly to the glass. The coating succeeds best when a very small portion of the reducing liquid is used, so as to cause the reduction to proceed slowly. To cause the precipitation of four and a half ounces of the solution of silver, from six to twelve drops of the reducing liquid are sufficient; and so thin is the film of metal thus deposited, that a square foot of it only weighs from twelve to eighteen grains. The principle of the process consists in deoxidizing the oxide of silver, by means of the volatile oil, which is effected without any evolution of gas, that might destroy the continuity of the metallic coating, while the nitric acid disengaged from the oxide of silver enters into combination with the ammonia.

Great as may appear the advantages of this process, it has not been applied extensively by the manufacturers of mirrors, partly on account of the difficulty of obtaining, by this means, a perfectly clear unspotted surface, and partly on account of the darker color of the silver coating, which gives a black effect to the mirror. This black appearance is probably due to the shade of the silver, although it has been also ascribed to the very perfection of the coating, and the precision with which it reflects the rays of light, whereas the ordinary coating of tin amalgam is crystalline, and reflects the light to the eye in almost any position.

The mixture now employed by Mr. DRAYTON is somewhat different from that above given, and consists of one part of ammonia, two parts nitrate of silver, three parts water, and three alcohol; this solution, being filtered, is mixed with one-fourth part of grape sugar dissolved in weak spirit. This method, or one very similar, is stated by PELOUZE and FREMY to be now successfully practised at Paris. The exact proportions given by them are as follow:—Six hundred grains of pure neutral nitrate of silver are dissolved in one thousand two hundred grains of water. To this solution are added:—First, seventy-five grains of a liquor prepared from twenty-five parts of distilled water, ten of sesquicarbonate of ammonia, and ten of ammonia, of specific gravity 0.980; second, thirty grains of ammonia, specific gravity 0.980; and, third, one thousand eight hundred grains of alcohol, specific gravity 0.850. The mixture is left at rest to become clear. The liquid is decanted or filtered, and a mixture of equal parts of alcohol—specific gravity 0.850—and of oil of cassia is added in the proportion of one part of this *essence of cassia* to fifteen parts of the argentiferous solution; the mixture is agitated and left to settle for several hours, after which it is filtered. Just before pouring it upon the glass to be silvered, it is mixed with one-seventy-eighth of its bulk of *essence of cloves*—composed of one part of oil of cloves, and three of alcohol, specific gravity 0.850. The glass having been thoroughly cleansed, is covered with the silvering liquid, and warmed to about 100°, at which temperature it is maintained for two or three hours; the liquid is then decanted, and may be employed for silvering other glasses. The deposit of silver upon the glass is washed, dried, and then varnished.

VOUL proposed to form the silver coating for the

interior of glass balls, *et cetera*, by dissolving gun-cotton in caustic potassa, with the aid of heat, adding to the brown solution a few drops of nitrate of silver, and the ammonia, until the precipitated oxide of silver is re-dissolved. This mixture is introduced into the glass ball, or other article to be loricated, and heated in a water-bath, when, after a certain time, the mixture becomes blackish-brown, froths up, and deposits all the silver upon the glass, forming a mirror which is said to reflect the light with surpassing brilliancy.

V. FLINT-GLASS.—This compound, which is commonly termed *crystal*, from its great resemblance to the natural production known as rock-crystal, is chiefly manufactured into articles of domestic use and ornament, such as tumblers, decanters, wine-glasses, vases, drops for chandeliers, *et cetera*. In consequence of its great transparency and high refractive power, it is also formed into lenses for optical instruments. On the Continent the term flint-glass is almost exclusively applied to glass which is expressly manufactured for the latter purpose, and *crystal* is employed as the more comprehensive designation for glass containing lead, of which flint or optical glass is regarded as a variety. In this country, flint-glass and crystal are used as synonymous terms, and that particular variety of this description of glass which is manufactured for optical purposes is termed *optical glass*.

Flint-glass is so called from the circumstance that, formerly, flints calcined and ground were employed in the manufacture as the source of the silica; but for many years past, Isle of Wight, Lynn, or Reigate sands have been substituted. These sands are not only more free from iron, but less expensive in the preparation than flints, when washed and calcined. Not only in this respect is the name inapplicable. To convey a correct idea of its composition, it ought to be termed lead or metallic glass, as the presence of a new element, *lead*, is that which distinguishes flint-glass or crystal from the different varieties of glass already mentioned. It is also distinguished from English crown and plate-glass by the use of potassa, instead of soda, in the manufacture.

DUMAS remarks that, by all the old writers, colorless glass, whatever be its nature or composition, is designated indifferently under the name of *crystal*. Thus, under this common designation, were confounded glass with a simple base of potassa, glass with a base of potassa and lime, and lastly, glass with a base of potassa and lead. It is necessary to be aware of this confusion, if one wishes to read with profit the old works on glass-making. At the present day, the term crystal or flint-glass is reserved to denote the double silicate of potassa and lead employed for the purposes already mentioned.

This beautiful variety of glass is admitted on all hands to be of English origin. Its invention was a natural and almost necessary consequence of the use of coal in the English manufactories—a usage which goes back to a very remote epoch. To prepare white glass in an open pot, with coal as fuel, is a problem which admits of being solved at the present day, but which could not be so at an early period. To protect the glass from the contact of the smoke which blackened

it, it was necessary to convert the common pot into a retort with a short neck, which presented its mouth outside the furnace. But under this condition, the vitrification became too difficult for ordinary glasses; it would have been necessary to increase beyond measure the proportion of alkali. It was essential, therefore, to find the means of increasing the fusibility of the glass, without rendering it deliquescent; and this was accomplished by means of a suitable addition of protoxide of lead. The beauty of the product soon assigned it a high rank among the different varieties of glass, and the manufacture of it was not long in extending even into countries where coal is not used. But in these localities the manufacture could be conducted in common pots, taking care to manage the wood fire, so as to avoid all production of smoke, and modifying slightly the proportion of the substances employed.

Flint-glass, however, is not entirely a modern invention, or, at least, if it was necessary to re-invent it, it is certain that it was known at a very remote epoch. This is demonstrated by the analysis of the ancient glass known as *Virgil's mirror*, an operation performed in 1787 by M. FOUGEROUX DE BONDAROY. This mirror, weighing thirty pounds, polished on both faces, transparent, but colored a yellowish green, contained at least half its weight of oxide of lead, and exhibited, moreover, all the characters of crystal. It had been preserved in the treasury of Saint Denis in France from the time of its fabrication, which assigns to its manufacture an epoch long anterior to the discovery of modern crystal. It is evident, indeed, that the name applied to the mirror is not correct, and proves nothing—that it did not belong to VIRGIL, and that it could not claim an antiquity so remote. This article only proves that the method of making lead-glass had been long known, and that the processes of the manufacture must have been well understood, since at that time a mirror could be formed of a size which would be deemed remarkable even at this day, and that the secret had been lost during a long succession of years. It may be affirmed, indeed, that the *colorless* crystal or lead glass of the present day, or, in other words, a crystal possessing that quality which constitutes its chief beauty and value, is entirely of modern invention. It is very natural to suppose that the method of making a colored crystal like Virgil's mirror might be known to many mediæval chemists, without assuming that they equally knew how to prepare a pure and colorless crystal like that now manufactured under the name of flint-glass.

Composition and Properties of Flint-Glass.—Five elementary analyses of crystal or common flint-glass have been given at page 192. The table in the same page, in which flint-glass is associated with strass and enamel, refers to that variety of flint-glass known as optical glass. From the former analyses it will be seen, that the composition of common flint-glass, after deducting the extraneous constituents, may be expressed by the following formulæ:—

- I. $\text{K}_2\text{O}, 2 \text{SiO}_2 + 3 (\text{PbO}, 3 \text{SiO}_2).$
- II. $3 (\text{K}_2\text{O}, 3 \text{SiO}_2) + 4 (\text{PbO}, 3 \text{SiO}_2).$
- III. $2 (\text{K}_2\text{O}, 2 \text{SiO}_2) + 3 (\text{PbO}, 2 \text{SiO}_2).$
- IV. $3 (\text{K}_2\text{O}, 2 \text{SiO}_2) + 3 (\text{PbO}, 2 \text{SiO}_2).$
- V. $\text{K}_2\text{O}, 2 \text{SiO}_2 + \text{PbO}, 2 \text{SiO}_2.$

In one case, therefore, triple silicates are the proximate constituents of the glass; in the others, double silicates. In fact, the proportions of the three essential constituents, namely, silica, potassa, and oxide of lead, vary according as the melting furnace is heated with wood or coal. In the latter case, the proportion of oxide of lead is increased. The following analysis by DUMAS has been already given at page 192, but is here repeated, to show the proportion of oxygen in the bases, as compared with that of the silica or silicic acid.—

	Centesimally.	Oxygen.	
Silica,.....	56	29	
Lime,.....	2.6	0.72	} 4.47 oxygen of the bases.
Oxide of lead,....	32.5	2.25	
Potassa,.....	8.9	1.50	
	100.0		

Here the oxygen of the bases is to that of the acid as 1 : 7. In the following analysis by M. BERTHIER, of a Vouêche crystal made with coal as fuel, the proportion is nearly 1 : 9 :—

	Centesimally	Oxygen.	
Silica,.....	61.0	=	31.7
Oxide of lead,....	33.0	=	2.3 } 3.3, oxygen
Potassa,.....	6.0	=	1.0 } of the bases.

These two analyses show, beyond all doubt, that the law of saturation of crystal or lead-glass varies within wide limits.

Many metallic oxides are capable of combining with silicic acid, and thus furnishing silicates which readily mix with alkaline silicates; but almost all these are colored. Till lately, the protoxide of lead and the oxide of bismuth were regarded as the only oxides capable of yielding silicates with little color, and, consequently, colorless glasses, by their mixture with the silicate of potassa in a proper proportion; but a *glass of zinc*, which had a very pleasing and white appearance, and was specially suited to achromatic purposes, was the subject of a reward at the Great Exhibition of 1851. This glass had the remarkable property of being of greater specific gravity, and much more pure and pellucid than lead-glass. It is to be expected, therefore, that the former may come into general use. On the contrary, the oxide of bismuth is much dearer than that of lead, and hitherto the latter has been alone employed in the manufacture of common crystal.

Crystal or flint-glass well prepared is almost without color. It is more transparent, more brilliant, and heavier than plate or window-glass. It excels the fine Bohemian crown-glass in refractive power and easy fusibility, although the latter is harder and more completely colorless. Flint-glass, of not less than the usual density of 3.200, well polished by the lapidary, is considered the nearest approach to the diamond. It owes its brilliancy and high density to the silicate of lead; but as the latter is itself yellow, it communicates a yellowish tint to the crystal when it preponderates over the alkaline silicate beyond a certain limit. There is also another reason for avoiding to use too much of it. The silicate of lead is much softer than the alkaline silicates. In too large quantity, therefore, it renders the glass so easy to scratch by the slightest friction, that it could not be employed for most of the articles

of domestic use or luxury into which it is fashioned. Moreover, this addition rendering it both heavier and more costly in the manufacture, would be at least useless, even if it were not absolutely prejudicial, for the reasons already mentioned. It is a common mistake to suppose that great density or *weight* is an advantage in crystal for articles of common use. It is, on the contrary, as DUMAS justly remarks, a real inconvenience, and, in the most favorable view, can only be considered as a ready means of showing that the crystal or flint-glass contains enough of silicate of lead to impart to it all the other qualities which give it its peculiar value, and render it preferable to other glasses for certain purposes.

As lead affords the only metallic oxide which is usually employed in the manufacture of flint-glass, so potassa is the only alkali which can be successfully associated with that ingredient to yield a colorless crystal. The silicate of soda always communicates a blue or green tinge, which would become more perceptible and disagreeable in the thick articles usually manufactured of crystal. If this thickness were much reduced, the silicate of soda might, so far as color is concerned, be used in the manufacture; but as crystal vessels are generally intended to receive mouldings or cut ornaments, they do not admit of being made thin in the sides. The annealing, also, would become a difficult operation in vessels of considerable size without a proportionate thickness. Crystal is so fusible that it is not easy to prevent such articles from sinking in, or collapsing, during the annealing. This kind of glass is, therefore, almost exclusively confined to the manufacture of thick articles; and hence it is only the colorless silicates that can be used—that is to say, those of lead, or zinc, and potassa. It is stated, indeed, that M. BONTEMPS uses soda instead of potassa, or a mixture of the two, in his recipe for optical glass; but this is an exception to the general rule, and requires explanation. The following practical recipes are given by M. BASTENAIRE for a good common flint-glass, the one with coal, and the other with wood as fuel:—

	With coal as fuel.	With wood as fuel.
	Pounds	Pounds
Sand—washed and calcined,...	100	100
Minium,	70	45
Purified potassa,	30	35

In addition to these, cullet or broken glass is added at discretion, and saltpetre or arsenic is used as a decoloring material. It will be seen that, when coal is used, the sand, red lead, and potassa are nearly in the proportions of 3 : 2 : 1; but that, when the composition is fused in open pots, with wood fuel, the proportion of the red lead is much diminished. The following composition, in which the above-mentioned proportions of the principal ingredients are exactly adhered to, is given by Mr. APSLEY PELLAT, as yielding a highly pellucid and transparent flint-glass:—

Carbonate of potassa, one hundredweight.
Red lead, or litharge, two hundredweight.
Sand—washed and burnt, .. three hundredweight.
Saltpetre, fourteen to twenty-eight pounds.
Oxide of manganese, four to twelve ounces.
Cullet, or broken glass, *ad libitum*.

Such is the most common proportion; but DUMAS affirms that a finer and more durable product is obtained by reducing the amount of alkali; thus, for three hundred parts of sand and two hundred of minium, ninety to ninety-five parts of purified carbonate of potassa, instead of one hundred, will yield a better result when the furnace draws well—in winter, for example. But in summer, the preceding proportions must be used, or the following French recipe:—

	Parts.
Pure sand,	300
Minium,	215
Purified carbonate of potassa,	110
Nitrate of potassa,	10
Borax,	12

It has been stated, that when open pots are used, as on the Continent, with wood fuel, the proportion of minium may be reduced. This arises from the circumstance, that the oxide of lead, being an active flux, is less necessary for the fusion in uncovered pots, which admit of the direct action of the heat on the contained mixture or metal. However, the use of the three essential ingredients in the ordinary proportion of three, two, and one, is, in all cases, a safe one. It is chiefly for economy that the minium is reduced in amount, when the heating power of the furnace is sufficient to permit the reduction. On the other hand, if the minium be too much reduced, the beauty of the product will suffer. The lowest proportion of this ingredient which can be used with safety is shown in the following composition, which yields a good crystal:—

	Parts
Sand,	300
Minium,	180
Purified carbonate of potassa,	120
Cullet,	300
Arsenious acid,	0.45
Oxide of manganese,	0.60

The mere due proportioning of the materials for flint-glass is not sufficient—the utmost attention must be given to have them in a state of purity. The silica or sand should be very white, and absolutely free from coloring oxides, as those of iron or manganese. Some manufacturers cleanse the sand by hand-washing, and others have machines. To render the Isle of Wight sand fit for making flint and other compound glasses—that is to say, to cleanse it from chalk and other impurities, by which it loses about one-fifth of its original bulk, requires about eight waters; it is afterwards passed through a heated arch, called a *calker*, and thoroughly dried, or burnt, at the discretion of the operator; and then sifted through a lawn-sieve, to separate the larger grains and pieces of coal or coke. DUMAS recommends that the sands be washed with dilute hydrochloric acid, to remove from them any traces of oxide of iron or of manganese.

The carbonate of potassa also requires a preliminary purification, which is easily effected by dissolving it in water, decanting the quite clear solution, and evaporating the liquor. All the coloring oxides are deposited, and by the evaporation carbonate of potassa is obtained, mixed with other salts, but at least quite free from oxides of iron or of manganese. If the nitrate of potassa were low in price, one might employ it to replace the carbonate.

The protoxide of lead, or litharge of commerce, is almost never pure. It contains oxides of copper, of iron, or of manganese, in too great quantity, in most cases, to admit of its making a colorless flint-glass. Moreover, an oxide of lead is expressly manufactured for the making of crystal. In general, there is selected for this purpose a very pure lead, which is carefully oxidized, to avoid introducing into it foreign and injurious matters. It is the practice to carry the oxidation of the lead to the state of *minium* Pb_3O_4 . Not that the crystal contains red lead; the latter loses by the action of the heat a portion of its oxygen, and passes again to the state of protoxide which alone forms part of the glass. But it is advantageous, and probably even indispensable, to furnish to the mixture which is to produce the flint-glass a body capable of yielding oxygen at the beginning of the fusion.

It has been supposed that this disengagement of oxygen was necessary to produce in the glass the agitation which prevents this product from separating itself in layers of different densities. But DUMAS observes that the decomposition of the minium must be concluded long before the fusion is effected. The oxygen which the minium disengages has very probably, for its object, to burn an organic matter analogous to ulmin,

which is found in large quantity in the crude salt; a matter which is decomposed in part, calcining this last to make potassa of it, but which is still found in the potassas of commerce in notable quantity. This matter, put in contact with the protoxide, would reduce it to the metallic state, and would color the crystal; whereas, being burned by the oxygen of the minium, it disappears, without leaving a trace of its existence.

It is evident that the same result would be arrived at by using nitrate of potassa instead of the carbonate, and that the minium might be replaced by pure litharge, or protoxide of lead. In point of fact, the small quantity of saltpetre which is usually added, exerts a beneficial effect, by increasing the proportion of oxygen, and assisting to drive off the globules of air in the liquid glass. This salt, when the price admits of its application, is at once a pure and a purifying material. A few ounces of manganese are employed to neutralize the greenish tint produced by the presence of iron or other impurities; and, with this view, the peroxide must be used in the purest crystallized state.

Melting and Fining of Flint-Glass.—The plan and sectional elevations of a melting furnace, figured at pages 199 and 200, are equally applicable to flint-glass, and other descriptions of glass, except that for bottle

Fig 179



and crown-glass the furnaces are usually oblong, and are only constructed to contain from four to six pots; whereas, for flint-glass works, round furnaces, containing from eight to twelve pots, are almost exclusively used. Mr. APSLEY PELLATT remarks, that ten pots

of thirty-six inches diameter are the medium number for a well-proportioned furnace, and are found the most economical for fuel. When the furnace has too large dimensions, too great an area is left unoccupied by the pots or fuel, and too small a furnace exposes the backs

of the pots to hang over the fire-place in the centre, which in time enlarges by burning away, and causes the pots to crack at the bottom, or back, by cold draughts through the fire-bars. According to the same authority, a furnace of twelve pots, exposing a much larger unoccupied area than a ten-pot furnace, will consume nearly double the quantity of fuel in uselessly heating the interior, whereas twelve pots of melted metal will hold only in the proportion of one-fifth increase. On the other hand, furnaces of less dimensions than eight pots are objectionable, through the great loss of pots, in consequence of the comparatively small size of the siege. In the Falcon glass-house, belonging to Mr. PELLATT—and from which have emanated many important improvements—there are two furnaces, instead of one, both opening into the same flue, as represented in Fig. 172, which shows also an interior view of the glass-house and working operations. By this arrangement, while one of the furnaces is in full operation the other may be undergoing repair, or the working of one may be entirely suspended without injury to the other, during a dullness of trade.

But the principal and only essential difference in the conditions for the melting and fining of flint-glass, consists in the shape of the pots, which, as represented in Fig. 142, page 201, are distinguished from those employed for other descriptions of glass, by being covered with a hood-shaped top, the mouth of which fits the working holes of the furnace, so that the smoke and heat cannot escape in the same way as in the usual glass furnaces. Open pots are used in some parts of France for flint-glass, with dried beech or oak-wood for fuel, and so little carbon is produced by the smoke as not to affect materially the metal, although the flames play upon its surface; but when coal or coke is used, as in this country, the fumes and smoke emitted would carbonize or deoxidize the lead, and precipitate it to the bottom in the original metallic state, if the pots were not covered; besides that the solid particles of soot would blacken the glass, by attaching themselves firmly to its surface.

The ingredients previously mentioned, having been carefully mixed together and sifted, are brought to the furnace in wooden vessels, like hand-barrows, and thrown into the pots in successive charges with an iron shovel. In this state the batch or frit, as the composition is called, is of a salmon color, the red tinge being derived from the oxide of lead. English melting-pots, which are usually much larger than the French, hold about eighteen hundredweight each, and the batch is introduced in quantities of about four hundredweight at a time, allowing a sufficient interval between each filling for melting down the various charges, until the pot is entirely filled with fused glass. By this method, says Mr. PELLATT, every pit in the furnace is fully charged with liquid metal in about twelve to fifteen hours; air-bubbles and striæ then abound, and they are not expelled until thirty to forty hours more have elapsed, during which period—namely, from fifty to sixty hours—the gas and air-bubbles are driven off, and the mass becomes homogeneous. During the founding, the mouths are securely stoppered and clayed up, and the furnace is urged to its utmost intensity. The shorter

the time of fusion and refining, the better; for this purpose the heat can scarcely be too great. With the best possible recipe, and the purest materials, good results depend upon an intense and continuous fusion: too little caloric will fail to refine the metal and drive off air-bubbles, and the coloring matter of the manganese; and too long continuance of intense heat will destroy the manganese, cause the glass to attack the pot, and become striated, gelatinous, and greenish. If the glass do not get fine by the usual time allotted, but becomes coddled or gelatinous, it never will recover, however urged by subsequent fusion. Such glass must be ladled into water, and considered only as cullet for re-fusion, with a proportion of new materials. The moment the metal is fully fused, and refined by continuous rapid fusion, the high temperature of the furnace should be reduced from its maximum heat to a working temperature; this period being considered *the crisis*. When flint-glass is kept in fusion beyond the crisis, it not only assumes a greenish tint by acting upon the iron of the Stourbridge clay-pot, but takes up a small portion of its alumina, which, by its inferior density, rises to the surface, frequently with detached portions of the pot, causing striæ and other impurities, which injure its quality for common uses, and render it entirely unfit for optical purposes. Formerly, *seam* or *sandiver* was allowed to run off, or was skimmed from the surface of the pots when opened for working, but the modern relative proportions and purity of the chemical materials are so good, as seldom to render this skimming necessary.—*Pellatt*.

Mechanical Operations.—The mechanical operations connected with common bottle glass, crown, sheet, and plate-glass, are uniform in their character; the description of the making of one bottle, or of one table, sheet, or plate of glass, applies to all. On the contrary, the infinite variety of shapes into which common flint-glass or crystal is manufactured, would render a complete account of the manipulations tedious, even if it were not in some degree foreign to the plan of this work. Only a few examples will, therefore, be selected, to illustrate the general character of these ingenious processes.

Flint-glass is either formed by simple blowing with the pipe, and then shaping by hand; or, secondly, by blowing in moulds; or, thirdly, by moulds alone, in which the glass is subjected to pressure. In each of these cases, the form and appearance of the article are very generally improved by grinding, cutting, *et cetera*.

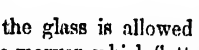
By way of illustration, the common tumbler may be mentioned as one of the simplest articles to make by hand.

In this case the workman collects on the end of the pipe a small quantity of glass—Fig. 173; this is rounded on the marver, expanded by blowing, and somewhat elongated by swinging, when it assumes the form—Fig. 174. The pipe is then suspended vertically, and the glass is allowed to drop by its own weight upon the marver, which flattens it at the extremity; and, being at the same time further

Fig. 173.



Fig. 174.



blown, it now resembles—Fig. 175. The pipe, with a portion of the glass, is then detached, by touching the



Fig. 175.

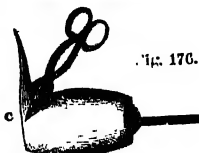


Fig. 176.



Fig. 177.

piece with the cold pucellas at A: this contracts and slightly fractures the glass, which is, subsequently, cracked through the entire circumference by a smart blow of the same instrument. In the meantime, the ponty has been attached by adhesion to the flat end, B, and the other end, which now corresponds to the dotted line, is first expanded with the pucellas, and then sheared as at C—

Part of the above process is omitted for common light cheap tumblers; these are not sheared, but simply flashed, and no pains is taken in subsequently polishing out the marver marks. Hence they are often ringy or wavy.

Wine-glasses are usually made in three pieces. The process is the same as for the tumbler, till the gathering assumes the shape represented in Fig. 175. A solid ball of glass is then attached to the flat end, as in Fig. 178, this being a separate gathering, out of



Fig. 178.



Fig. 179.

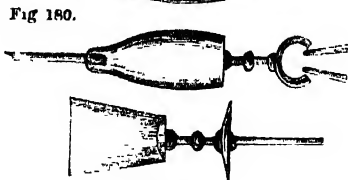


Fig. 180.



Fig. 181.

which the stem is shaped by the pucellas, while it is rotated on the inclined planes of the glass-maker's chair. It then assumes the form represented in Fig. 179. To form the foot, a small hollow globe is now attached to the stem, which is afterwards opened by the pucellas, as in Fig. 180; and when the pipe, with a portion of the glass, is separated from the other end, and the mouth expanded, sheared, and flashed, the glass finally assumes the form represented in Fig. 181.

To make a ringed decanter, the glass, by the process already described, is brought to the form represented in Fig. 182. The ponty is then attached to the flat end,

and the mouth is warmed up, and shaped with the pucellas, as in Fig. 183. Another workman then gathers upon a ponty a small piece of glass, which is dropped on near the mouth, as shown in the same figure, and, by rotating the decanter, the entire circle or ring is welded by contact, and its surplus tapered and torn suddenly off. By re-heating the

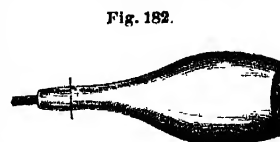


Fig. 182.



Fig. 183.

decanter, a second, third, and fourth ring may be added, as shown in Fig. 184.

The process of blowing and moulding common green glass bottles has been briefly described at page 210. Bottles and other articles of flint-glass are blown and moulded in much the same manner, but



Fig. 184.

the finer descriptions are afterwards cut and ground. Moulded glass never exhibits a full lustre, nor even the sharpness of the metallic mould. The glass, not being perfectly liquid, does not penetrate into the sharp corners, nor does it even accommodate itself perfectly to the flat sides of the mould. Hence the edges are blunt, and the surface is never perfectly even, but more or less curved and wavy. Moulded articles can, therefore, never be compared with cut-glass, but some are now produced of remarkable beauty; and even as a preparatory step to grinding, the use of moulds is of great advantage, as the vessel acquires a regular form, and presents, although in a crude state, all the prominent and receding features, to be perfected at the lathe.

The moulds for flint-glass are carefully constructed of brass or iron, and, when of simple construction, are somewhat wider at the upper part, that the pieces may be easily removed, or are composed of more than one piece when projecting parts are to be moulded. A common *open and shut mould*, such as is used for apothecaries' phials, as well as for common wine-bottles, is shown in Fig. 185. It is constructed in two exact



Fig. 185.

halves, connected with a bottom hinge. The glass to be moulded is gathered on the pipe, rolled on the marver into a cylindrical form, and then pinched with

the pucellas at the end attached to the pipe, to form the neck of the bottle. The cylindrical mass, still adhering to the pipe, is then inserted into the mould lying on the ground; its two halves are shut; and the workman blows through the tube, which renders the mass of glass hollow, while it receives from the mould the external form required. With this form of mould two seams or lines are produced, by the two sides of the mould not shutting quite closely. In round bottles these seams are unsightly, but they are scarcely perceptible in square bottles, as the joinings of the mould are placed at two of the corners.

This imperfection, though not entirely removed, is much diminished by the use of an improved mould, invented by Mr. PELLATT, and represented in Fig. 186. It consists of one piece, D, for the body, and two pieces, B B, for the neck. By this construction the seam down the body, so objectionable in round bottles,

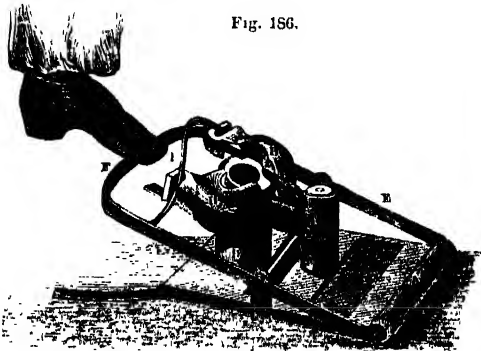


Fig. 186.

is avoided, although the neck is still marked by two slight seams. The neck-pieces, which are kept open by a spring, C, are brought together, after the insertion of the globe or spheroid of metal, by the guide, E, on pressing down the treadle, F, with the foot. The workman then blows through the pipes, and, on raising his foot, the counterweight, A, falls, and the bottle is readily taken out.

Moulded Roman Pillars.—With reference to this species of moulding, recently introduced by the English manufacturers, Mr. PELLATT remarks that it owes its refractive and cut-like effect to its inequalities of substance, the interior having no indentations to correspond with its exterior projections. In this case the mould is only about one-third the size of the object to be manufactured. The metal is first gathered upon a pipe in the ordinary manner, except that the first gathering is allowed to cool more than

usual, and the second coating is pressed into the mould, A—Fig. 187—as hot as possible, so that only the exterior portion may be acted on by the mould, while the

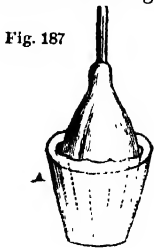


Fig. 187.

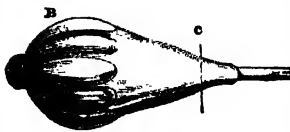


Fig. 188.

interior preserves its smooth circular section. When about half-formed, the projecting parts, B—Fig. 188—have a centrifugal enlargement given to them by a sharp trundling of the iron at, or immediately after the blowing.

During the re-heating process, the piece is separated at the dotted line, C, has a foot welded to it, and is rewarmed as D—Fig. 189. It is then sheared, as E—Fig. 190; and when finished by flashing, shaping,

et cetera, so as to appear as in Fig. 191, it is known as patent pillar moulding. A little cutting or scolloping makes this refractive moulding still more ornamental; but though it much resembles cutting, as to its round

pillars, it is inferior where sharp angles are required. Pillar moulding is, however, one of the greatest modern improvements, and is used advantageously for lamp-pedestals, chandelier work, toilet-bottles, salt-cellar, *et cetera*, at very moderate cost.—*Pellatt*.

It may here be remarked that all bottle-moulds require, while working, to be kept nearly at a red heat, either by a small furnace, or by a piece of hot glass held inside by a boy on the end of a pony-rod during the intervals of the moulding. This precaution is essential to the polish, but the heat of the moulds must be kept below redness, otherwise the glass would adhere to them.

Pressing.—The third method of manipulation with flint-glass, is moulding by pressure—an American invention, which consists in dropping the soft metal into a prepared die, and then pressing down the matrix or plunger upon it by means of a lever. The chief conditions of success in this operation are, to take care that sufficient glass is introduced to fill the mould, and that the latter is kept at a steady temperature, a little short of red heat, to produce a polished surface. When the die or mould is once formed, articles are produced in this way with great rapidity; but much practice and dexterity are required to gather the exact quantity of metal. Under this head may be mentioned



Fig. 192.

drop-pinching, or the moulding of drops for chandeliers, girandoles, and candlesticks. In this case, lumps of glass made expressly for the purpose, are first softened by a blast-furnace, and then shaped in twin-dies, A B—Fig. 192. Arms of chandeliers are formed

Fig. 189.

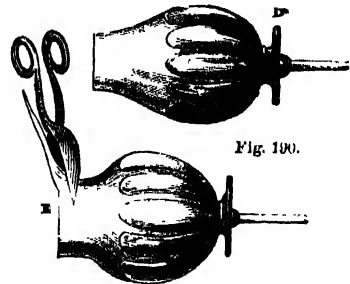


Fig. 190.

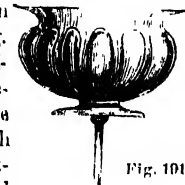


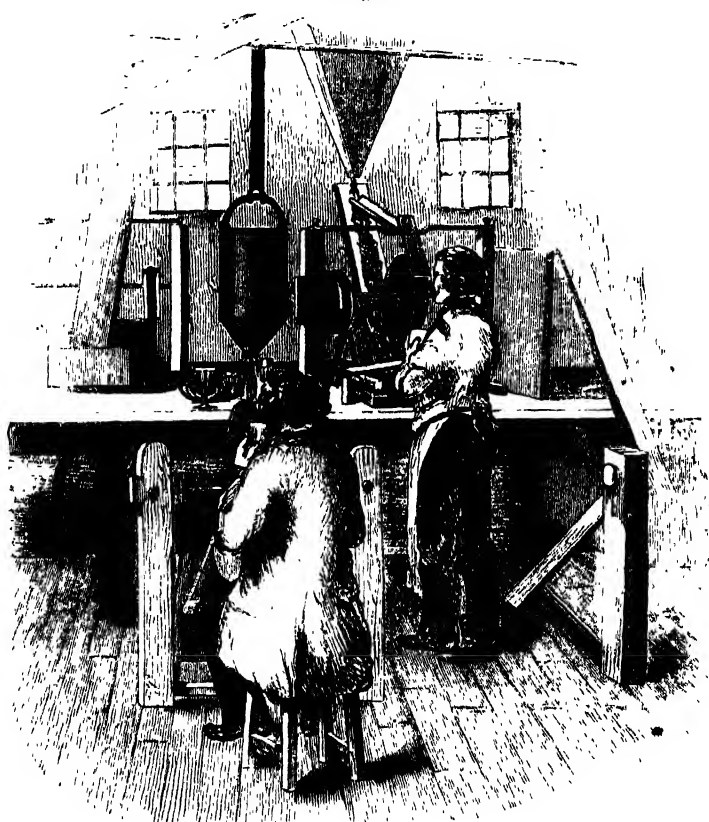
Fig. 191.

on the same principle, but using a powerful leverage press. Both arms and drops are afterwards cut and polished, to produce the required brilliancy.

Cutting and Polishing.—The finishing process which gives to the finer articles manufactured of flint-glass their distinguishing beauty, is technically termed *cutting*, but is actually performed by grinding. The inferior hardness of flint-glass renders it fitter for this purpose than any other glass. The operation, as represented in Fig. 193, is performed by discs of iron, sandstone, or copper, revolving in a lathe which is

usually propelled by steam power. The edges of the discs, which are sharp, angular, or rounded, according to the work to be performed, are supplied with sand and water dropping from a hopper for *rough grinding*, and with emery for *fine grinding*. A stone-wheel with water is employed to smooth out the rough sand-marks, and prepares the glass for the *polishing*, which is effected by means of a willow-wood disc, first with a mixture of pumice and rotten-stone, and finishing with a preparation of tin and lead, termed putty-powder. All table-glass ware and hollow articles are thus cut.

FIG. 193



Chandelier drops are cut or ground with iron and stone-wheels in the same manner, but are finished with a lead-wheel supplied with a little very fine rotten-stone and water.

For many years the practice has been introduced of roughing lamp-lustres by means of sand. It is easy to conceive how the exterior roughing may be performed, but the rubbing of the interior surface appears a more difficult operation. It is, in fact, performed on a somewhat different principle. In this case, sand of a uniform grain is put into the globe or lustre; a certain number of these globes are arranged in a drum or cylinder, and a rapid rotatory movement is given to the latter, by means of which the interior surfaces of all the globes are quickly worn and roughed in a very equal manner.

Glass-Engraving.—Small copper discs of the size of

a halfpenny, and finely pulverized emery mixed with oil, are used to execute the outline and ground of the glass-engraver's work; and for polishing, lead-wheels and very finely pulverized emery are employed. Coarse patterns for hall-lamps are engraved by the glass-cutter's smoothing wheel; and Mr. PELLATT remarks that the contrast of the polish of a wood-wheel upon a ground roughed by sand is often effective, though the range of pattern is somewhat curtailed by the large size of the cutter's ordinary wheels rendering it difficult to execute curvilinear designs. For inscribing initials, coats of arms, and minute designs, very small discs must be employed. The finest incisions are made with copper pencils, either pointed, or ending in a button-like disc.

Etching on Glass.—It has been stated at page 199, that hydrofluoric acid, either in the gaseous or liquid

state, exerts a peculiar action on glass, which has been turned to account as a substitute for cutting or engraving designs; and though not confined in its application to flint-glass, the process may be appropriately described in this place.

For etching on glass by means of the gaseous acid, the glass is cleaned, well dried, heated, and melted varnish poured upon it, which is spread in a homogeneous coating. This varnish is formed of wax and turpentine; it ought to be soft enough to admit of being removed by the burin without scaling it off; it is generally formed of one part of turpentine to four parts of wax. When the glass is cold, the varnish acquires a little opacity, but not so much as to prevent tracing through it. The burin is then passed over the varnish, following the lines of the figure, and cutting through the varnish to the glass. When the figure is traced, the glass so prepared is exposed to the action of hydrofluoric acid. For this purpose a leaden tray or earthen vessel is used; in this is put fluoride of calcium pulverized with concentrated sulphuric acid; it is mixed well, and the vessel is then placed on a very gentle fire, and the glass to be etched is laid over it. At the end of some minutes from the time when the vapor begins to rise, the operation is terminated; the glass is then taken off, and the varnish is removed by melting it, and wiping with a soft linen rag.

If, instead of exposing the glass to the action of the acid vapors, it is plunged into the weak liquid acid, the same effect is produced in a few moments.

But when it is desired to produce a very pure and correct figure, with half-tints and strong shades, recourse must be had to a longer and more delicate process; a particular varnish, too, must be used.

The best is drying linseed oil, or, better still, fat varnish of copal blackened with lamp black, perfectly pulverized, and sprinkled with oil of turpentine. The coatings laid on must be very thin, and each should be quite dry before putting on a new one. The glass is sufficiently covered with varnish when the light can scarcely be seen to pass through it. The design is then copied through, and the varnish is removed from the lines with the points of gravers, or simple needles of different forms and sizes. For greater convenience, the design is lighted from below by inclining it at an angle of about 45° on a desk pierced for a window. The position of the glass enables one to perceive the most delicate lines.

After having formed the figure, it must be corroded out with liquid hydrofluoric acid; but before commencing this operation, it is necessary to test the glass as well as the acid. This preliminary trial is made on a small piece of the same glass, covered with the same varnish. This piece is divided into five or six parts; on each of these parts some traces are drawn with the needle, and the operator covers them successively by means of a pencil with liquid hydrofluoric acid. A minute is allowed to intervene between each operation, so that when the acid has acted during one minute on the last portion, it has then been in contact with the glass for two minutes on the preceding one, and for six minutes on the first. This being done, the slip of glass is washed with plenty of water, and the varnish is re-

moved by means of a knife and spirits of turpentine. It is then easy to determine the proper time for allowing the acid to act upon the design to be etched.

BEDFORD patented a peculiar process for etching glass, which consists in grinding five parts of peroxide of lead and one part of flux, composed of seventeen parts glass of borax, and thirteen parts of red lead, fused together. The peroxide of lead employed is puce-colored, and with the above composition the artist paints the devices or designs upon the surface of the glass. When the etching is to be done on colored glass, acetate of lead is substituted for the oxide. The article is then dried, and fixed in the same manner as in gilding glass. When cold, it is dipped in a weak solution of nitric acid, and as soon as the painted designs are acted on, it is placed in water, and the preparation removed from its surface.

On the whole, it must be admitted that etching by fluorine acid, though practised to some extent, and in some particular cases with marked success, has not been found effective for general purposes. It is usefully applied, however, to form the scales on thermometer tubes, and written or printed inscriptions on glass vessels. The attempt to make it subservient to typographical purposes has been a failure.

OPTICAL GLASS.—There are two kinds of optical glass—flint and crown—which, having different refractive and dispersive powers, may be so combined in the object-glass of a telescope that, while the rays are brought to a focus, the greater dispersion of the flint lens may be corrected by the less dispersive power of the crown—the one being negative, the other positive. Hence, by their combination, the lenses achromatize each other, or transmit colorless light. The celebrated DOLLOND, in 1753, aided by the co-operation of EULER, and of KLINGENSTIERNA the Swedish mathematician, succeeded, after many experiments, in discovering the due proportions of the curvatures of the two lenses; but still two important problems remained to be solved—the best chemical constitution of the glasses, and how to obtain them sufficiently free from the defects of ordinary glass to be adapted for optical instruments. It is this last question which presents the greatest difficulty. Purity, unchangeableness of color, transparency, and a certain degree of refractive power, may be obtained; but perfect uniformity in the structure of the glass, so as to render its composition absolutely homogeneous throughout, is much more difficult to be accomplished; and this is precisely the quality which is admitted to be the most indispensable for good optical glass. The difficulty arises chiefly from the difference in specific gravity of the different constituents of the metal. Some melt at a lower temperature than others; some evaporate or are decomposed in a heat required for the fusion of others; and different substances cool at different temperatures. Hence arise discoloration, threads, striae, irregular crystallization, causing irregular refraction, and all the usual faults observable, more or less, in every description of glass.

It seems to be now generally admitted that there are more impediments in fabricating crown-glass lenses of large size, than in making good ones of crystal or flint-glass. The former requires a higher temperature, and

by adding alkali to increase the facility of fusion, it becomes more liable to attract humidity, or, as it is technically termed, to sweat. On the other hand, by rendering it too hard, one incurs the risk of crystallization and imperfect vitrification in cooling.

For a long period, however, the principal attention of opticians and glass-makers was devoted to the manufacture of a suitable flint-glass, which was considered to present the greater difficulty of the two. Occasionally, the flint-glass manufacturers found in their pots a portion of glass suitable for opticians; but this was an accidental product. The problem of the constant and regular manufacture of good optical flint-glass still remained to be solved, when M. GUINAND, a workman in the clock and watch trade, near Neufchatel, who had been accustomed to the fusing of metals in the prosecution of his business, devoted his attention to the subject, and succeeded in producing masses of flint-glass capable of furnishing objectives of nine inches—a size previously unknown. Even the celebrated chemists, MACQUER ROUX of St. Gobain, and AUV of Langres, had never been able to obtain them of larger diameter than three to three and a half inches. M. DARTIGUES also, one of the first manufacturers of flint-glass in France, and who to his high reputation for practical skill added that of scientific knowledge, equally failed of success. GUINAND's discovery was therefore hailed with much satisfaction; but he kept the process a secret, except from M. UTZSCHNEIDER and the celebrated M. FRAUENHOFFER, who proposed to him to join them in their establishment at Munich. This offer GUINAND accepted, and the process was successfully worked by them for several years without any one being able to discover it. After their deaths, one of GUINAND's sons being in possession of his father's method, continued the manufacture of optical glass in the environs of Neufchatel. The other son formed an association with M. BONTEMPS, one of the directors of the glass-work of Choisy-le-Roi, but the experiments which were made by them conjointly at that establishment did not succeed. The treaty was therefore broken; but M. BONTEMPS and his co-director, M. THIBEAUD-DEAU, satisfied of the correctness of the principle, if properly applied, continued their experiments without excluding GUINAND; and ultimately, in 1828, they succeeded in producing good optical glass in discs of from twelve to fourteen inches, and a large quantity of smaller sizes. From that time the manufacture has been established on a regular system. In 1848, M. BONTEMPS was induced, in consequence of difficulties arising from the political state of the country, to retire from his position at Choisy-le-Roi, and to accept the invitation of Messrs. CHANCE, Brothers, and Company, to unite with them in attempting to improve the quality of this important branch of manufacture. How far they have succeeded may be judged of from the fact, that they have produced discs of flint-glass twenty-nine inches in diameter, weighing two hundredweight, and of crown-glass up to twenty inches. These discs are pure in color, good in structure, and exempt from those defects which tend to polarization of light. BONTEMPS' proportions for optical glass are as follow:—

FOR FLINT-GLASS.

Sand,	43.5
Red lead,	43.5
Carbonate of potassa,	10.0
Nitrate of potassa,	8.0
	100.0

FOR CROWN-GLASS.

Sand,	60
Carbonate of soda,	25
Carbonate of lime,	14
Arsenic,	1
	100

It will be observed that optical flint-glass is chiefly distinguished by the large proportion of lead which enters into its composition. According to DUMAS, who approached very near to the truth in assigning its probable composition, its density should not be lower than 3.6 at least. The essential point in the manufacture, however, consists in the constant stirring of the metal during the melting and fusing. The superiority of GUINAND's plan is considered not to have been in the novelty of the materials or proportions, but in carefully agitating the liquid glass while at the highest point of fusion, then cooling down the entire contents of the pot in a mass, and, when annealed and cool, separating unstriated portions by cleavage. It is worthy of remark, that some time before GUINAND's death, a commission of the Astronomical Society of London, composed of Messrs. HERSCHEL, FARADAY, DOLLOND, and ROGET, having been instructed to conduct an inquiry into the manufacture of flint-glass for optical purposes, arrived at the result that the necessary improvement was chiefly mechanical, not chemical, and that freedom from striae could only be obtained by a constant agitation of the mixture. FARADAY, who took the lead in the inquiry, both in his own laboratory and at the glass-works of Messrs. PELLATT, changed, however, the composition, as well as the principle of fabrication, and produced a borate of lead of remarkable purity. This substance, known as FARADAY's heavy glass, which has proved so important in experiments connected with the polarization of light by magnetic action, is composed of the following ingredients:—

Protoxide of lead,	104
Silicate of lead,	24
Dry boracic acid,	25

This glass required but a red heat for fusion, thereby, as Mr. PELLATT remarks, offering facilities for minute agitating operations. It was found, however, not to be durable, and therefore not calculated for application to optical purposes or general use. The common process for making optical glass is described by Mr. PELLATT as follows:—A ladle, in the form of a sugar-loaf, about five inches in diameter and seven inches deep, is dipped carefully into the metal, which has been previously skimmed; when filled, it is taken out of the pot, and suffered to get partially cool. To the large end of the sugar-loaf-shaped piece of glass thus produced, a glass-blowing iron with a hollow disc is welded, and placed to the opening or mouth of the pot for reheating; when sufficiently soft, it is blown into a muff; the end furthest from the blowing-iron is cut off, the cylinder is flattened into pieces or plates of fourteen inches long, ten inches wide, and about half an inch thick, and annealed; in

which state the plates are sold to the optician for cutting and grinding into discs.

Zinc Optical Glass.—Allusion has already been made to a new kind of glass which was sent to the Great Exhibition of 1851 by M. MAËS of France, and was honored with a Council medal, as an instance of novelty of chemical application in the manufacture of optical and other descriptions of glass. The basis of this vitreous compound was oxide of zinc—a certain quantity of borax or boracic acid being added, to give the glossy character for which the boracic compounds, no less than the silica, are so eminently remarkable, combined with an easier fusibility. Its extreme limpidity, and total freedom from color, veins, and striæ, appeared to the council jury eminently to fit it for telescopes, prisms, and other optical apparatus—as a substitute, however, not for the flint-glass, but for the crown, in achromatic telescopes. The low dispersive power of the zinc compounds points to the use of glass of zinc for this purpose. Its refractive index is 3.285, and its dispersive ratio, as compared with a flint-glass of specific gravity 3.55, is as 0.6502 to unity. With reference to this peculiar glass, the following passage occurs in the Report of the Council Jury on Optical Glasses:—Suppose it should be found practicable—and the experiment is recommended to the attention of artists, as one in which, when tried on a very small scale, some success has actually been obtained—to form colorless and uniform glasses, in which fluorine enters as a distinguishing ingredient, in combination with silica, alumina, or other materials; the combination of such glass, as a convex lens, with this new material of M. MAËS, or with ordinary crown-glass as a concave, might be expected to produce achromatic object-glasses of a very perfect description. The colored dispersion to be removed being much less than that of crown-glass, owing to the peculiarity of the fluorine compounds which beset the manufacture of flint-glass, arising from the intense solvent power of the oxide of lead on the crucibles, and give rise to striæ and veins, would be evaded. M. MAËS, besides two prisms of his new glass, of the most limpid purity, and perfect freedom from veins or striæ, exhibited two discs of four and a half and seven inches in diameter, prepared for optical use. In an examination, through faces cut on their edges, no veins or striæ were detected, and, consequently, should there arise no objection to this material, either in point of durability or facility of working, it will probably prove very valuable for the use of the optician.

VI. STRASS AND COLORED GLASS.—The manufacture of glasses tinged, colored, or stained, by different processes, has now become a business of great and growing importance. The taste for stained-glass windows, which formed so distinguished a feature in the history of a former period, has revived, and is now displayed in the decoration, not only of splendid palatial and ecclesiastical structures, but even of many private dwellings; the skill of the Venetians of a former day, in producing colored vases and other ornamental articles of glass of every variety of hue, is equalled if not surpassed in modern times; and artificial gems, or pastes, which are true glasses, are now formed, that emulate,

if they do not eclipse, in sparkling lustre and pure transparency, the rarest and most beautiful natural productions of the mineral kingdom.

Although all the varieties of glass can be colored at pleasure by virtue of the property possessed by the greater number of the heavy metallic oxides of producing colored compounds with silica, yet in individual cases it depends upon the object in view, and even on the nature of the color, whether a glass void of lead, or a lead-glass with its higher refractive power, is employed as the basis for the coloring material. In general, however, the basis of the color, or that with which the coloring matter is actually mixed, is a lead-glass, and this, when real *glass-painting* is the object, is applied either as a pigment or in a melted state on common glass or some other finished article; in other cases, the colored lead-glass is itself formed, cut, or moulded into the finished article. When the latter is an artificial gem or paste, a peculiar glass is employed, termed *strass*, which it may be proper to describe in this place, before proceeding to give a short account of the different coloring materials, and the different methods of their application in particular cases.

Strass, so called from the name of its inventor, constitutes the only true glass not yet described, and forms, as above stated, the basis of artificial imitations of precious stones. For this purpose a glass is required, possessing the highest degree of purity and transparency, combined with the greatest possible lustre. These requirements are found in a composition analogous to that of flint-glass, but containing a much larger proportion of oxide of lead and a little boracic acid. DONAULT-WIELAND recommended, by way of example, either of the three following mixtures:—

	No. 1.	No. 2.	No. 3.
Ground rock-crystal,...	100	—	100
Sand,	—	100	—
Pure minium,	176	—	174
White-lead,	—	171	—
Purified caustic potassa,...	51	32	56
Boracic acid,	7	9	6
Arsenious acid, ..	.3	.3	.16

From these proportions, and from the analysis of a strass manufactured by DONAULT-WIELAND, which was given at page 192, it will be seen, that not only does the oxide of lead greatly exceed in amount that which is contained in crystal or common flint-glass, but that it is present in larger proportion than even in optical flint-glass. This will be observed by glancing at the same table in the page above-referred to, where flint-glass from GUINAND, or, in other words, optical glass, is placed in juxtaposition with strass and enamel. The very large proportion of oxide constitutes, in fact, the distinguishing peculiarity of the former, while the latter is further distinguished by containing oxide of tin, or is in reality a strass with a mixture of oxide of tin or stannic acid.

Strass, when well prepared, possesses as nearly as possible the high refractive power and all the other properties of the diamond, except its hardness. When cut into shape, therefore, without the addition of any coloring matter to its composition, it answers for imitating the diamond. On the contrary, when tinged by

silicates with metallic bases, it furnishes imitations of all the colored stones. For this purpose its perfect purity and high lustre are essential requisites. It is necessary, therefore, to exercise great care in the choice of the materials. The rock-crystal, quartz, or sand employed, must be of the purest description. The last two always contain a little iron, which colors the glass yellow, and should therefore be washed with hydrochloric acid after being carefully pulverized. The potassa must not be mixed with any other salts. DONAULT-WIELAND preferred the finest caustic potassa; but DUMAS remarks that the use of the nitrate might be preferable on account of the constant purity of that salt. The borax of commerce—that of Holland, for example—would produce a brown glass; crystallized boracic acid is therefore preferred. The oxide of lead employed is very pure minium.

DUMAS remarks that the choice of the crucibles is very important, and that the Hessian ones are better than those of porcelain. The crucibles sometimes color the metal yellow or brown, when particles of iron are detached from the internal surface. This inconvenience is not to be apprehended with crucibles of hard porcelain, but these often break or run out, and are too permeable. A pottery or porcelain furnace is used to melt the material, and the crucibles remain in the fire about twenty-four hours. The more tranquil and prolonged the fusion, the greater hardness and beauty does the strass acquire. If the crucibles are of excellent quality, a porcelain furnace may be used; but when the loss occurring is too great, one must be contented with a common potter's furnace.

COLORING MATERIALS.—It has been stated that colorless strass is the basis of artificial gems, most of which are formed by mixing with the strass certain coloring materials. In the article ENAMELS, many of the substances employed for this purpose have been enumerated; but further details may now be given in connection with the general subject of *colored glass*, before proceeding to the special proportions employed for imitating certain precious stones.

Yellow is produced either by charcoal, antimony, silver, or oxide of uranium. The charcoal, incorporated with the glass in a very fine state of division, produces a dirty yellow, which, as the quantity increases, passes into a dark brown without lustre; it is, therefore, little used as a pigment. A much superior yellow is obtained by roasting sulphide of antimony to the state of antimonious acid, and melting it with from 3 to 5 per cent. of undecomposed sulphide of antimony. An *orange yellow* is prepared with glass of antimony, minium, and a little oxide of iron. In these cases, the substances so prepared are mixed with the materials of the glass. When silver is employed, the process is quite different; in this case a mixture of powdered clay and chloride of silver is applied to the surface of the ready-made articles, and on reheating these in a muffle, the silver penetrates to a certain depth into the glass even before the latter softens; the article is then allowed to cool, and the coating which was applied is scraped off, when a yellow color of great purity and brilliancy appears on the glass. It is remarkable that this effect can only be produced on glass containing alumina, which shows

that the action is chemical, and not purely mechanical. Oxide of uranium produces a beautifully delicate yellow of a slightly greenish hue, which is attributed to the traces of iron usually found in the commercial oxide; but this pigment is too costly for common use.

Red, of different shades, is communicated by oxide of iron, suboxide of copper, or different preparations of gold, mixed with other materials. The oxide of iron— Fe_2O_3 —is employed either as pure oxide, prepared by heating the nitrate, or in the state of bloodstone or ochre. This substance, added to the glass mixture, produces a cheap and very common brownish red. The peculiar action of suboxide of copper has already been explained under ENAMELS, vol. i. page 821. This substance was much employed by the artists of the fifteenth and sixteenth centuries, for producing the brilliant red colors of window panes, and in later times the glass so colored was supposed to be indebted to gold for its beautiful rich hue. So intense is the coloring power of this oxide, that even a very small quantity reddens the glass so much as to render it opaque, and hence it is almost impossible to command any desired tint in applying it. Even a common window pane is scarcely permeable to the light when coloured with a small portion of this substance; and hence in crystal vessels, which are necessarily of much greater thickness, especially when intended for grinding, the effect becomes excessive—the glass is rendered quite opaque. To obviate this difficulty, recourse is had to the process of *flashing* or coating white with colored glass, as will be explained afterwards—a process so successful that it was subsequently extended to other colors.

The application of gold to produce a brilliant red color, which, according to circumstances, can be made to assume a scarlet, carmine, rose, or ruby tint, was first introduced by KUNKEL, who used for the purpose the brownish-red precipitate produced in a solution of chloride of gold by a salt of the sesquioxide of tin. This substance, known as the purple of CASSIUS, was long believed to be the only preparation of gold which could be employed for this purpose, till FUSS demonstrated that ruby-colored glass may be obtained when the powdered ingredients for the glass are mixed, previous to fusion, with oxide of tin and the solution of gold; the mixture then appears like moist grey sand. Experience has further shown that the simple addition of a solution of gold to the flux, without any oxide of tin, is capable of producing rose and carmine-colored glass.

Blue is produced by oxide of cobalt, a pigment which is equally applicable to lead-glass and to glass containing no lead, but in the latter the color is more intense. The coloring power of the oxide of cobalt is so intense, that pure white glass is rendered sensibly blue by the addition of one-thousandth part of the oxide. Ample information as to the methods of preparing blue cobalt glass, which is produced in a pulverized state as a pigment, under the name of *small* or *saffre*, has been given in the article COBALT.

Green may be produced either by protoxide of iron, protoxide of copper— CuO —or oxide of chromium— Cr_2O_3 . The tint produced by the first of these substances has little brilliancy. The oxide of copper yields

a beautiful emerald. For this purpose the glass is mixed with the product obtained by heating copper to redness with access of air, or with powdered verdigris, which is then decomposed in the fire, and converted into oxide by oxidizing agents. Care must be taken to prevent the protoxide of iron from being converted into sesquioxide, and the oxide of copper from being reduced to suboxide. The oxide of chromium, which occurs as a pigment in commerce, yields the purest and most brilliant grass-green hue, but is too costly for common use.

ARTIFICIAL GEMS.—The preceding cases may be sufficient to illustrate the general character of the substances employed to tinge glass, whether in the fabrication of artificial gems, or in the more important art of enriching with color articles of common use or ornament. Before proceeding to this latter subject, which embraces different methods of applying the coloring material, the following may be given as the most approved recipes for imitating those precious stones that are deemed of highest value:—

Diamond.—Colorless strass, without any addition.

Topaz.—DONAULT recommends the following mixture:—

Very white strass,.....	1000
Clear yellowish orange-red glass of antimony,..	40
Purple of Cassius,.....	1

A very good imitation of topaz is obtained from—

Strass,.....	1000
Oxide of iron,.....	10

Topaz, when obtained by the first of these two compositions is very subject to vary in tint during the fusion, according to the temperature and the time it is exposed to the fire. It passes from the colorless strass-white to a sulphur-yellow, violet, and reddish purple, according to circumstances, which are not well understood. This substance may be compared to the *rubin-glass* of the Germans and Italians. The glass of antimony must be selected of the greatest transparency, and of a clear orange-red yellow.

Ruby.—This is the rarest and most highly prized of artificial stones. The preparation of topaz furnishes a means of obtaining constantly and at pleasure very fine rubies. The mixture for topaz often gives an opaque mass translucent at the edges, and presenting in its thin plates a color red by transparency. One part of this opaque topaz-matter, and eight parts of strass melted in a Hessian crucible, when left thirty hours in the fire of a potter's furnace, give a fine yellowish crystal similar to strass. Remelted with the blowpipe, this produces rubies of the finest water.

A ruby not so fine, and of a different tint, may be made by employing the following proportions:—

Colorless strass,.....	1000
Oxide of manganese,.....	25

Emerald.—The emerald is very easy to imitate. That which succeeds best results from the mixture of the oxide of copper with colorless strass. If oxide of cobalt be added, the green obtained presents blue reflexions. The composition which gives the best imitation of natural emerald is as follows:—

Colorless strass,.....	1000
Pure oxide of copper,.....	8
Oxide of chromium,.....	0.2

By increasing the proportion of chromium or oxide of copper, and adding oxide of iron to the mixture, one may vary the green shade, and imitate peridot or dark emerald.

Sapphire.—To produce a fine oriental blue color, one must employ very white strass, and very pure oxide of cobalt. This composition, put into a luted Hessian crucible, should remain thirty hours in the fire. The proportions are as follow:—

Colorless strass,.....	1000
Oxide of cobalt,.....	15

Amethyst.—The color of this stone must be fine and velvety, to be of any value. The formula which succeeds best is the following:—

Colorless strass,.....	1000
Oxide of manganese,.....	8
Oxide of cobalt,.....	5
Purple of cassius,.....	0.2

Aqua-marina is a gem in little request—even the real stone. As generally met with, it is of a pale emerald tint, but the most valuable kind is colorless like the diamond. The colored kind is obtained by mixing—

Colorless strass,.....	1000
Glass of antimony,.....	7
Oxide of cobalt,.....	0.4

Syrian Garnet.—This stone, which was anciently termed *carbuncle*, has a lively color, for which it is much esteemed. It is especially employed for small jewels. The artificial garnet is a kind of dark ruby, and is made after the following formula:—

Colorless strass,.....	1000
Glass of antimony,.....	500
Purple of cassius,.....	4
Oxide of manganese,.....	4

In the fabrication of artificial stones, there are many precautions to be taken, many points to be observed, which can only be acquired by experience. The materials must be pulverized with great care. The mixtures can only be well made by repeated sifting. The same sieve must not be used for sifting different compositions, whatever care be taken to clean it after each operation. Lastly, to obtain masses well melted, quite homogeneous, without striæ or bubbles, it is necessary to employ substances very pure, and mixed in a state of extreme division; to obtain the best crucibles, to melt with a graduated heat, in a furnace which is quite equal in its maximum temperature; to leave the metal in the furnace during twenty-four to thirty hours, and to cool the crucibles very slowly, that their contents may undergo a kind of annealing.

COLORED FLINT-GLASS.—Assuming as the composition of the glass to be colored the common ingredients and proportions quoted at page 230, and remembering that these materials, when mixed together, are technically termed *batch*, and, when fused with the usual precautions, produce a highly pellucid flint-glass, this may be regarded as the basis of the following colored glasses, given on Mr. PELLATT's authority:—

Soft White Enamel.—To six hundredweight of batch

add twenty-four pounds of arsenic, six pounds of antimony.

Hard White Enamel.—To six hundredweight of batch add two hundred pounds of putty prepared from tin and lead.

Blue Transparent Glass.—Six hundredweight of batch colored with two pounds of oxide of cobalt.

Azure Blue.—Six hundredweight of batch with about six pounds of oxide of copper.

Ruby Red.—Six hundredweight of batch with about four ounces of oxide of gold.

Amethyst or Purple.—Six hundredweight of batch with about twenty pounds of oxide of manganese.

Common Orange.—To six hundredweight of batch add twelve pounds of iron ore and four pounds of manganese.

Emerald Green.—To six hundredweight of batch add twelve pounds of copper scales and twelve pounds of iron ore.

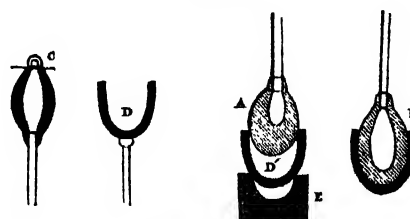
Gold Topaz Color.—Six hundredweight of batch with three pounds of oxide of uranium.

FLASHING AND CASING.—In speaking of the sub-oxide of copper, it has been stated that the coloring power of this substance is so intense that even a very small quantity of it renders the glass opaque; and allusion was made on that occasion to the process of *flashing*, by which the difficulty is overcome, and which, on account of the facilities it affords for regulating the intensity of the tint, has been extended to the manufacture of articles of every variety of hue. This process consists in coating a layer of colorless, with one of colored glass, which can then be reduced, by grinding, to the proper tint. For this purpose the glass-blower collects the proper quantity of colorless glass on the end of his pipe, rolls it upon the marver, and then dips it for a moment into a pot of melted colored glass, and blows out the two together into a cylinder or globe, which is flattened or *flashed* out in the usual way. In this manner panes for the glass-painter are formed, which consist of two layers of glass, one colored, the other colorless; and the former can be ground down to any required tint or degree of transparency. An ingenious application of this process is made to vessels of flint-glass, which are tinged on the outside in a similar manner, and colorless edges or facets are then produced by cutting through the outer layer of colored glass, into the substratum of pure white glass.

Flint-crystal glass is usually colored by a somewhat similar process termed *casing*, and thus described by Mr. PELLATT. Presuming that any two or more glasses intended for casing have been mixed of the same specific gravity, to give them the capability of harmonizing—that is, of contracting and expanding equally—the blower has to gather a ball of solid glass, intended for the interior layer, in the usual manner, as A, Fig. 194, which, in this instance, may be considered to be of white crystal glass. About the same time his assistant prepares a casing of colored glass, B, knocking off the knob at C, to open and shape it, as D, somewhat like the bowl of a wine-glass, or the broad end of a large egg-shell; this is set into a metal stand, E, on the floor, merely to steady the case or shell, D'; while the blower takes the lump of flint or white glass, A, and

gently blows it into the colored case or shell, D', to which it immediately adheres; and when submitted to

Fig. 194.



the flame of a pot-hole, it is found to weld perfectly, as F. If various coverings are needed, as many colored shells must be prepared as required, and each time melted in by fresh warming, until the entire number are obtained and cased. The whole are afterwards rewarmed, expanded, and shaped into vases, tazzas, or such other articles as the manufacturer requires, by blowing, and the usual appliances of moulds, tools, rotatory motion, *et cetera*. When cut through to the crystal in various figures, the edges of the different colors on enamel are seen.

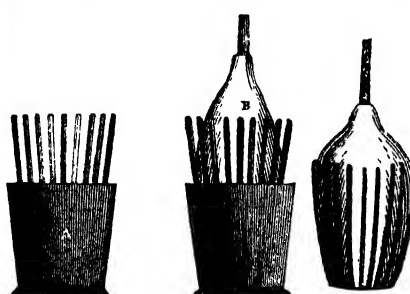
In connection with *flashing* and *casing*, may be mentioned a variety of methods of producing colored or variegated or ornamental glass, some of which are very ingenious, and are chiefly derived from the Venetians.

Venetian filigree work is produced in the following manner:—Pieces of *cane*, or solid rods of glass, of different colors, having been drawn out in the same manner as tubes, and whetted off to the required lengths, are arranged in the flutes or internal grooves of a cylindrical mould, A, Fig. 195. The blower then inserts a solid ball of transparent flint-glass, B, Fig. 196, and the whole is exposed to a welding heat, till the

Fig. 195.

Fig. 196.

Fig. 197.



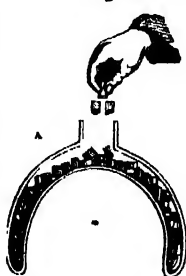
canes adhere to the ball. Both are then withdrawn with it from the mould, when the piece presents the appearance represented in Fig. 197. When again heated, drawn, and twisted, the streaks of color produced by the adhering canes become spiral, and ornament the surface. If well softened and marvered before the drawing and twisting, the streaks spread till they meet; or if, before being drawn, the mass be re-dipped into the pot of crystal glass, and then twisted, the spiral lines of color or enamel become internal. By the repetition of this process, spirals can be formed

within spirals; and by placing the filigree canes side by side, and welding them together, very curious and intricate patterns are obtained.

The *Venetian ball* is simply a number of pieces of waste filigree glass collected together without regular design; they are then introduced into a globe of transparent glass, which is made to collapse upon the filigree fragments within by suction; that is to say, by the blower drawing in his breath. The round heavy paperweights, which generally contain regular devices, are formed in the same manner, and the lens-like shape of the crystal enhances the effect by magnifying the incrustated ornament.

The *mille-fiore* or *star-work* of the Venetians is formed by placing lozenges of glass, cut from the ends of colored filigree canes in the interval between two transparent cones, as shown in Fig. 198, and then, after reheating the whole, exhausting or sucking out

Fig. 198.

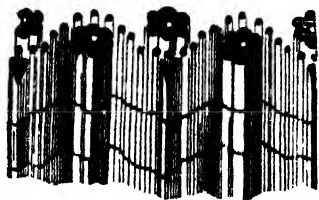


the air by means of a blowing-iron attached to the neck, A. The piece being then rewarmed becomes one homogeneous mass, which can be shaped into any required form, for tazzas, paperweights, *et cetera*. In forming such incrustations, it often happens that, from the unequal contraction between the object and the crystal by which it is surrounded, there is much difficulty in the annealing, and, to avoid the

risk of fracture, the contained object must be made of materials expanding and contracting like the glass or crystal itself.

Glass-mosaic, which is often confounded with *mille-fiore*, is produced by threads or small canes of variously colored opaque or transparent glass, of uniform lengths, ranged vertically side by side, in single threads or masses, so that the ends shall form grounds agreeably to some prefigured design. When submitted to heat sufficient to fuse the whole, the four sides at the same time being pressed together so as to exclude the air from the intervals between the threads, the result will be a thick slab of variegated glass—Fig. 199—exhibiting, for all parallel sections, the same figure or pattern.

Fig. 199.

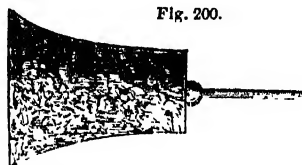


Hence, when cut into veneers, either in the direction shown by the dotted lines, or obliquely or longitudinally, it will yield a number of slabs or layers of the same uniform design. The thin rods of glass employed for this purpose are composed of very easily fusible glass of all possible colors and shades, and are prepared in manufactories erected expressly for this purpose.

In these manufactories, masses of colored glass are prepared, from which a kind of cake is formed, and this is converted, with the aid of a sharp hammer and an anvil, first into slabs, and then into the thin rods above-mentioned. In this form the material is supplied to the artist, who softens it in the flame of a lamp, draws out each rod into a thick thread, and breaks off a piece of the thickness of the intended picture. These pieces are then arranged one after the other, according to the design, on a slab of copper covered with a layer of cement, which serves to fix the picture. When the whole slab is covered, the surface, which is necessarily uneven and irregular on account of the unequal lengths of the rods or threads, is ground and polished. It is unnecessary to observe, that a large mosaic painting formed in this manner is often a work of years.

Venetian frosted glass is obtained by immersing the gathering of hot metal in cold water, quickly withdrawing it, reheating and expanding it by blowing, before it becomes so hot as to melt and weld together the numerous superficial cracks produced by the momentary immersion in cold water. These cracks only penetrate so far as the metal has been cooled by the water, and remain as depressions until the article is finished, when it presents the appearance represented in Fig. 200.

Fig. 200.



The art of making this glass was kept secret by the Venetians, but was rediscovered by Mr. PELLATT a few years ago.

Mr. PELLATT has also invented a method of ornamenting glass with delicate white argentine incrustations of dry porcelain clay, cemented into the solid glass. For this purpose the hot prepared cameo, which may be a small bas-relief or cast, is placed upon the red-hot manufactured vessel or other article; a small piece of liquid glass is then dropped on it, and becomes welded; and if rubbed while hot, the upper coat of fused glass will be spread as thinly as possible upon and around the cameo, behind which are driven any air-bubbles that may be entrapped; thus completely isolating the device between the two glasses. The polishing of the exterior layer gives the white figure a silvery appearance; but, of course, the incrustation may be colored before being applied to the glass. These incrustations require very careful annealing.

Venetian vitro-di-trino is a sort of lace-work, formed by intersecting lines of white enamel, or transparent lines of white or colored enamel or transparent glass, the centre of each mesh or diamond inclosing an air-bubble. It is formed by blowing a gathering in the mould with suitable canes arranged in the interior fluting, as shown in Fig. 195, page 241. It is then reheated, further blown and twisted, as for spiral filigree, the canes being left projecting from the outside, like ribs. By the usual manipulation, a cup or conical

vessel is formed, marked by oblique lines or spiral projections, as shown in Fig. 201. Another similar piece is then made and turned inside out; the projecting canes on this piece are inside, and the spiral lines reversed. The one piece is then placed under the other, as shown in Fig. 202, and the two are welded

Fig. 201.



Fig. 203.



Fig. 202.



together. The ribs or flutes projecting from the two surfaces in contact inclose, during the welding, a portion of air in each diamond, which air gradually assumes the bubble-shape. The vessel is then finished in the ordinary manner, and the lines exhibit the most beautiful regularity, as shown in Fig. 203.

Aventurine Glass is an easily fusible brown, or, in thin layers, yellow glass, interspersed with numerous fine yellow laminae or spangles with a metallic lustre, which give it a peculiar shining appearance. The method of manufacture was long kept secret by the Venetians. It was commonly supposed that aventurine glass was produced by melting scales of metal or mica with the glass; but this opinion was thought to be overthrown when GAHN observed that, under the microscope, these scales appeared as regular three or six-sided tables, perfectly crystalline in structure. He discovered, in fact, that the spangles consisted of metallic copper, crystallized in the form of flat segments of a regular octahedron. FREMY and CLEMANDOT succeeded, however, in preparing this glass by fusing together, for twelve hours, the following mixture:—

Pounded glass,	300 parts,
Copper scales,	40 „
Iron scales,	80 „

and afterwards cooling slowly. The glass obtained was somewhat deficient in lustre, but, like the true aventurine, it contained copper diffused through it in octahedral crystals.

GLASS-PAINTING.—Painting on glass is performed by means of a vitreous mixture termed the flux, combined with a pigment prepared from some metallic oxide. The flux and oxide are simply that combination of ingredients which is necessary to produce a highly fusible colored glass of the required hue; this mixture is reduced to a state of fine powder, rubbed up in oil of turpentine, boiled oil, or sometimes simply with water, and laid upon the glass to be painted, by means of a brush. The glass thus painted or stained with the intended design is then exposed to a heat

sufficient to vitrify the mixture of color and flux, without melting the glass; in other words, the painting is said to be burnt in; the ingredients of which it is composed are converted into a colored glass or transparent picture, while the pane or other article on which it is laid, is only sufficiently softened to cause the complete adherence of the colored glass to its surface.

It is evident, therefore, that the fusing-point of the pigment must be much lower than that of the glass to be painted. Indeed, it is necessary that the former should vitrify at a temperature at which the latter does not sensibly soften; for any considerable softening or yielding of the glass would distort the design. Hence the manifest inapplicability of crystal or lead-glass for painted articles, on account of its great fusibility. On the other hand, common window-glass, or even plate-glass, may be successfully used, and, best of all, the hard Bohemian glass, which contains potassa for a base.

When the coloring oxides employed are such that they are not injuriously affected by the oxides of lead and of bismuth, the flux is usually composed of the following ingredients:—

	Parts
Quartz in powder,	100
Oxide of lead,	125
Oxide of bismuth,	50

But if these oxides exert an injurious action on the coloring matter, and tend to change its shade, the subjoined composition is used:—

	Parts
Quartz in powder,	100
Fused borax,	75
Nitrate of potassa,	12.5
Carbonate of lime, free from iron,	12.5

To either of these mixtures or fluxes the proper coloring matter is added, and the composition so formed is introduced into a crucible, and melted into a colored glass. The latter is then reduced to a fine powder, mixed, as has been stated, with oil of turpentine, and used as a common pigment for painting on the less fusible glass. In this operation, a cartoon, or drawing upon paper, is placed below the glass, and the colors are applied on the corresponding lines. In preparing painted sheets or panes of glass, brown or black outlines are generally traced on the one side of the sheet, whilst the colors are laid on the other side; but in painting vessels or other articles, this is not the practice.

One great difficulty of the glass-painter consists in this, that the colors which he lays on have not the same appearance as they are intended to assume in the finished work. The difficulties of the artist on glass, says Mr. TOMLINSON, are of a much more formidable character than those of the artist on canvas; he must be as good an artist as the latter, but he must also have the faculty of seeing his effects as they will appear after the firing, and not as he lays them on; for the coloring oxides which he employs, especially when mixed up in their fluid vehicles, are dark, dusty, and disagreeable in color, and have nothing in common with the bright and beautiful effects we admire in a stained-glass window. When the same figure or pattern is to be repeated many times, it is, in some cases,

printed on the glass with a gentle pressure from an engraved metallic plate, or wooden block, boiled oil being used as the vehicle for the coloring oxide. The pane, having been prepared either by painting or printing, is exposed in an oven or muffle to a temperature sufficient to fuse the vitreous flux and dissolve the coloring material. The glass selected for the purpose of the stainer should be clear and colorless, in order to bring out the colors well; and difficult of fusion, so that the flux and metallic oxide may form a colored glass upon its surface before it shows any tendency itself to fuse. A glass containing a small proportion of alkali, such as crown-glass, is fit for the purpose.

SPUN GLASS.—There is no one who has not heard statements relative to the discovery of a malleable glass, one memorable instance of which is mentioned in the Historical Notice, page 186. If, by malleable glass, be understood a glass capable of being spread out into thin plates under the action of the hammer at the ordinary temperature, everything leads to the belief that this marvel never was, and will not for a long time be realised. If, on the contrary, it means only the ductility of incandescent glass, there remains in this respect little to be accomplished. It is, in fact, on this property that the whole art of the glass-maker depends. But whilst, in the ordinary operations of glass-making, the ductility of the glass is never pushed to its utmost limits, these limits are almost reached in the curious art of spinning glass into thread.

The art of spinning glass consists in drawing it out into threads when softened, by means of a wheel on which the thread is wound. By this means the art has been attained of spinning glass with astonishing rapidity. The drawn out end of a glass rod has only to be attached to a revolving drum, whilst the rod whence the thread proceeds is held in the glass-blower's lamp, in order to obtain in a few minutes several ells of spun glass. The thread possesses, of course, the color of the glass; but its tenuity is so great that the color is scarcely perceptible, unless very deep shades have been employed.

It has already been stated that when a piece of hollow glass is drawn out, the hole is always preserved, however fine be the thread. M. DEUCHAR took a piece of thermometer tube, the interior diameter of which was very small, and drew it out into threads. The drum which he used was three feet in circumference, and as it made five hundred turns per minute, he obtained thirty-two thousand ells of thread per hour; so that the thread was of extreme fineness, and its interior diameter was scarcely calculable. This thread was, however, hollow; for being cut into pieces of an inch and a half in length, and placed on the receiver of an air-pump, one end inside and the other out, it allowed the mercury to pass through in small shining filaments when a vacuum was made in the receiver.

The thread obtained from a small piece of window-glass, cut with a diamond, presents a very brilliant lustre; seen with the microscope, it exhibits a flattened form, with four very distinct right angles. It is very probable that it owes to this particular form the superiority of its lustre, for the threads obtained from round pieces of glass had always a dull appearance.

When glass of different colors is fused or welded together in one tube, the thread obtained from it preserves all the original colors without any mixture taking place, or any interruption being observable; but most of the colors become tarnished by the operation, particularly the yellow, which disappears; the black even sometimes passes to brown; the purple and green are a little altered, but the blue stands well.

The samples of spun glass are as pliable as silk, and may easily be wound in the manner of common thread, and employed as ornaments. To the touch they feel like hair, and like it may be curled in a permanent manner by rolling them on a hot iron. Threads from black glass have so much resemblance to black hair, that they are often confounded. It is well known that in the last century perukes were manufactured of glass thread, which is sometimes still used to make very brilliant head-dresses. Its glossy appearance, its great durability when not exposed to rough usage, as well as the low price of glass, naturally suggested to manufacturers the advantage of making it a material for spun fabrics. It has even been woven into stuffs, but hitherto this curious manufacture does not appear to have been attended with much success. It has been alleged, indeed, not without reason, that articles of clothing made of glass might be attended with some danger from the filaments becoming detached, and being drawn into the lungs by respiration. KNAPP states, however, that this branch of manufacture has lately been revived with success by OLIVI, DUBUS-BONNEL, and BOUILLON; and that DUBUS, in particular, is said to have succeeded in producing glass thread that can be knotted, and woven on JACQUARD'S loom into fabrics which are equal in every respect to the most beautiful gold and silver brocade. He adds that the particulars of this manufacture have not yet been made public, and the Editor cannot help thinking that its success has been greatly exaggerated.

VII. SOLUBLE GLASS.—Soluble glass is a compound, the knowledge of which would have spared the glass-makers many faults. It is, as has been stated, a simple silicate of potassa or soda, or a double silicate of these two bases. What is remarkable, this body is soluble in boiling water without a residue, though scarcely affected by contact with cold water. Nevertheless, it is very evident that such a glass must be strongly hygrometrical, and, among the numerous examples which might be cited, the Editor limits himself to the following, to show the inconveniences which arise from this. In 1780, Bohemian glasses, the process for which was then a recent importation, were made simultaneously in France by the two following receipts:—

	At Bayel in Champagne.	At Elmboe in les Vosges.
Silica,	100	100
Potassa,	100	100
Lime,	none	100

Now, while the Vosges glass was unalterable by the air, that of Champagne was wanting in clearness, brilliancy, and solidity, and attracted the moisture of the atmosphere to such an extent, that the hollow feet of drinking-glasses became filled in the warehouses with

a saturated solution of carbonate of potassa. To this fact, one might add many others which would prove the indispensable necessity of lime or of oxide of lead, for the making of glasses to be capable of resisting the action of water or of moist air.

Soluble silicated alkali or water-glass may be prepared by various processes. If sand be used, fifteen parts of fine sand, thoroughly incorporated with eight parts of carbonate of soda, or with ten of carbonate of potassa, and one of charcoal, fused in a furnace, will produce a silicated alkali which is soluble in boiling water. MESSRS. RANSOME obtained this silicated alkali by dissolving broken flints in a solution of caustic alkali at a temperature of 300°.

This water-glass has been applied to several important purposes, three of which are especially noticed.

To protect Building-stones from decay.—The stone surfaces of buildings, by being exposed to the action of the atmosphere, become liable to disintegration from various causes. Moisture is absorbed into their pores. The tendency of their particles to separate in consequence of expansion and contraction, produced by alternation of temperature, is thus increased. Sulphurous acid is always present in the atmosphere of coal-burning cities, and cannot but corrode the calcareous and magnesian ingredients of oolites and dolomites. It is true that good stone resists these sources of injury for an indefinite time, but such a material is rarely obtained. As a preventive of destruction, whether arising from physical or chemical causes, it has been proposed to saturate the surface of the stones with a solution of water-glass.

It is well known that the affinity of silica for alkali is so feeble, that it may be separated from this base by the weakest acids, even by carbonic acid. According to the expectation of those who recommend the silification of stone, the carbonic acid of the atmosphere will set the silica free from the water-glass, and the silica thus separated will be deposited within the pores and around the particles of the stone. The points of contact of these particles will thus be enlarged, and a sort of glazing of insoluble silica will be formed, sufficient to protect the stone from the effects of moisture, *et cetera*. This cause of protection applies chiefly to sandstones. But wherever carbonate of lime or carbonate of magnesia enters notably into the composition of the building stone, then an additional chemical action, also sheltering the stone, is expected to take place between these carbonates and the water-glass. An insoluble salt of lime may be looked for, whenever a solution of water-glass is made to act on the carbonates of lime or magnesia existing in oolitic or dolomitic building stones.

This expectation, however, has not been altogether realized by experiment. Mr. CHARLES A. SMITH, a gentleman eminently conversant with building materials, immersed a piece of Caen-stone in a solution of silicate of potassa in the month of January, 1849. This fragment, together with a portion of the block from which it had been detached, was placed on the roof of a building in order that it might be fully exposed to the action of atmosphere and climate. After five years the silicated and the unsilicated specimens were found to be both in the same condition, the two being equally

corroded. But whatever ultimate results may ensue from this process, the immediate effects on the stone are remarkable. Two portions of Caen-stone were exhibited, one of which had been soaked in a solution of water-glass two months before. The surface of the unsilicated specimen was soft, readily abraded when brushed with water, and its calcareous ingredients dissolved in a weak solution of sulphurous acid. The silicated surface, on the other hand, was perceptibly hard, and resisted the action of water and of dilute acid when similarly applied.

Another proposed use of the water-glass is that of *hardening cements, mortar, et cetera*, so as to render them impermeable by water.

Fourteen years since, ANTHON of Prague proposed several applications of the water-glass. Amongst others he suggested the rendering mortars waterproof. He also suggests that this substance might be beneficially employed as a substitute for size in whitewashing and staining walls. It was demonstrated by several experiments that carbonate of lime, mixed up with a weak solution of water-glass, and applied as a whitewash to surfaces, was not washed off by sponging with water, and that common whitewash, laid on in the usual manner with size, was rendered equally adhesive when washed over with water-glass.

The Stereochrome of FUCHS.—The formation of an insoluble cement by means of the water-glass, whenever the carbonic acid of the atmosphere acts on this substance, or whenever it is brought in contact with a lime-salt, has been applied by FUCHS to a most important purpose. The stereochrome is essentially the process of fresco-sicco invested with the capability of receiving and perpetuating works of the highest artistic character, and which may be executed on a vast scale. This chemist's method is as follows:—

Clean and washed quartz-sand is mixed with the smallest quantity of lime, which will enable the plasterer to place it on the wall. The surface is then taken off with an iron scraper, in order to remove the layer formed in contact with the atmosphere; the wall being still moist during this operation. The wall is then allowed to dry; after drying it is just in the state in which it could be rubbed off by the finger. The wall has now to be fixed, *ad est* moistened with water-glass composed as follows:—

	Centesimally.
Silicic acid,	23.21
Soda,	8.90
Potassa,	2.52
Water,	65.37
	100.00

The specific gravity of the solution is to be 3.81. This operation is usually performed with a brush. The wall must be left in such a condition as to be capable of receiving colors when afterwards painted on. If, as frequently happens, the wall has been too strongly fixed, the surface has to be removed with pumice, and to be fixed again. Repaired in this manner, the wall is suffered to dry. Before the painter begins, he moistens the part on which he purposes to work with distilled water, squirted on by a syringe. He then limns: if he wishes to repaint any part, he moistens again.

As soon as the picture is finished, it is aspersed over with water-glass. After the wall is dry, the syringing is continued as long as a wet sponge can remove any of the tint. An efflorescence of soda sometimes appears on the picture soon after its completion. This may either be removed by syringing with water, or may be left to the action of the atmosphere. Not to dwell on the obvious advantages possessed by the stereochrome over the real fresco—such as its admitting of being retouched and its dispensing with joinings—it appears that damp and atmospheric influences, notoriously destructive of real fresco, do not injure pictures executed by this process.

The following crucial experiment was made on one of the pictures. It was suspended for twelve months in the open air, under the principal chimney of the New Museum at Berlin; during that time it was exposed to sunshine, mist, snow, and rain, and nevertheless retained its full brilliancy of color.

The stereochrome has been adopted on a grand scale by KAULBACH, in adorning the interior of the great national edifice at Berlin, already alluded to. These decorations consist of historical pictures—the dimensions of which are twenty-one feet in height, and twenty-four and three-quarters in width—single colossal figures, friezes, arabesques, *et cetera*. On the effect of the three finished pictures, it has been remarked by one whose opinion is entitled to respect, that they have all the brilliancy and vigor of oil paintings, while there is the absence of that dazzling confusion which new oil paintings are apt to present, unless they are viewed in one direction, which the spectator has to seek for.

Mr. A. CHURCH has suggested that, if the surface of oolitic stones—such as Caen-stone—is found to be protected by the process already described, it might be used, as a natural *intonaco*, to receive colored designs, *et cetera*, for exterior embellishings; the painting would then be cemented to the stone by the action of the water-glass.

Mr. CHURCH has also executed designs of leaves on a sort of terra-cotta, prepared from a variety of WY's silica rock, consisting of seventy-five parts clay, and twenty-five of soluble silica. This surface, after being hardened by heat, is very well adapted for receiving colors in the first instance, and retaining them after silication.—*Timbs*.

KUHLMANN remarks that the contact of lime with silicate of potassa, always determines the decomposition of this salt and its transformation into silicate of lime, which retains the coloring matter, and even carbonic acid, as lately supposed by M. FUCHS; but when the colors are applied on bodies which do not react on the soluble silicate—such as wood, iron, glass, *et cetera*—it becomes necessary to seek for conditions of insolubility in the reaction of the coloring matter on this silicate. On wood the difficulty may be removed by the application, before the silicious painting, of a sufficiently thick covering of chalk, which may be applied with zinc, or fixed with a very little silicate.

Even when the decompositions of the alkaline salt are determined by the coloring matter itself, there still remains one serious inconvenience: this is the exudation, during damp weather, of carbonate of potassa to

the complete expulsion of the salt. This chemist for a long time sought for a remedy for this serious injury to silicious paintings; he often conferred on this subject with those members of the Academy best acquainted with vitrification, and having been aided by their advice, KUHLMANN sought in various chemical changes for a remedy, and ascertained that washing the painting with a weak solution of chloride of ammonium, enables one to attain absolute insolubility of the color, but chloride of potassium remains, which spoils its brilliancy until its complete expulsion by repeated affusion with water. As the number is but small of chemical reagents, which have the property of consolidating potassa by forming with it insoluble compounds in the color itself, but without eliminating it, perchloric acid and hydrofluosilic acid are the chemical agents which first offer themselves to the mind.

In a theoretic point of view, there only remained to choose between them; but, in an industrial sense, hydrofluosilic acid was the only one on which his mind fixed itself. He ascertained so frequently that careful washing with hydrofluosilic acid much augmented the stability of these colors, and determined their complete insolubility, that he did not hesitate to point out the utility of this agent in every kind of silicious limning, but especially in painting on glass, provided that it is used in very weak solution; for in the concentrated state it has the remarkable property of dissolving most of the oxides, which property will be very valuable for industrial purposes, when this acid can be sold at a moderate price.

The silicious colors on glass have a certain semi-transparency which it is important to preserve, but which gradually diminishes by the action of water. Glass painted with silicates has been subjected to boiling in water without the colors being detached; these tints have even appeared brighter when seen by reflected light; but if, after this apparent improvement, the effect is examined by transparency, the hues are found to have become duller, which is to be attributed to the opacity which they had acquired, resulting from the solution of a portion of silicious cement, which acts on these colors as oil does on paper. The careful employment of hydrofluosilic acid gives a complete insolubility to paintings on glass; but, like chloride of ammonium, it slightly diminishes the transparency. One might perhaps apply, at long intervals, a slight varnish of pure silicate of potassa to paintings on glass which are exposed to rain. Long experience can alone determine this point. This varnish would advantageously replace the essences now used in the application of certain colors on glass and porcelain; it would not, like the essences, be subject to the drawback of spoiling certain colors by the reduction of the oxides or of the coloring salts.

STATISTICS.—Considering the vast importance of glass, and the peculiar facilities possessed by Great Britain in her ample stores of coal, and the possession of nearly all the materials for the manufacture, it might have been imagined that this country would not only have fully supplied her own wants, but would long ago have furnished a large portion of the world with glass, as with many other exports. It might be sup-

posed, also, that the various necessary, convenient, and ornamental purposes to which glass is applied, would have been held as a sufficient reason for exempting it from taxation, or at least for reducing the duties to the lowest possible limit. But so far was this from being the case, that the most exorbitant duties were imposed, and were exacted in the most oppressive manner; which not only limited the demand for glass, by directly increasing the price, but operated indirectly with most injurious effect, by fettering the operations of the manufacturers, and preventing them from making experiments, and introducing new processes and improvements.

As illustrative of the amount of the duties, which are exhibited more at large in the appended tables, it will be seen that in 1813 they were raised to not less than four pounds eighteen shillings a hundredweight on plate and flint glass, and three pounds thirteen shillings and sixpence on crown. With such enormous duties on one of the modern necessities of life, the result of ignorant legislation, it was impossible for this country to enter into fair competition with other nations, or even to keep pace with a rapidly increasing population. On the contrary, despite the increase in population, and the still greater increase in wealth in the interim, the consumption of flint and plate glass in 1813, and many subsequent years, was less than it had been in 1794, when the duty on these glasses was only one pound two shillings and twopence farthing a hundredweight. Again, it is stated by the late Mr. PORTER, that in 1801, with a population of only sixteen millions, the quantity of glass used was three hundred and twenty-five thousand five hundred and twenty-nine hundredweight; and in 1833, with a population of twenty-five millions, the quantity was no more than three hundred and sixty-three thousand four hundred and sixty-eight hundredweight—an increase of one-eighth, while the population had increased in the proportion of one-half.

By the imposition of the income-tax, the late Sir ROBERT PEEL was enabled to abolish, along with many other injurious indirect taxes, the excise duties on glass, which were repealed from the 5th April, 1845; and MACCULLOCH justly remarks, that the beneficial influence of this liberal and most judicious measure is obvious in the improved quality, the increased cheapness, and greater variety of descriptions of glass in the market. At the meeting of the Society of Arts, in 1856, to which reference has already been made in the course of this article, Mr. W. A. SWINBURNE, of the celebrated glass-making house of that name, alluded to the different price of glass in former times, as compared with the present; speaking of three shillings and sixpence or four shillings a foot as having been paid to glaziers now living for glazing ordinary-sized crown glass in sashes, for which now, perhaps, only as many pence could be obtained. In the case of plate-glass, he held in his hand a tariff used by their house, dated 1771, two years before the establishment of the British Plate-Glass Company, wherein the price of a chimney mirror fifty inches long by forty inches wide, a very usual size, and now in common demand, was quoted at sixty-one pounds three shillings! The price of this plate before

the repeal of the duty in 1845, was nine pounds nine shillings to ten pounds; after the repeal of the duty, about eight pounds; in 1854, four pounds ten shillings; and in 1855-6, about four pounds four shillings. So much had the public benefited by the reduction of the price of glass.

But, as may be supposed, this reduction in price, as well as the great improvement in quality, did not solely arise from the mere repeal of the duties. It arose also, in great measure, from the removal of those intolerable fetters which were previously imposed on the manufacturer by the excise regulations. During the excise reign, says Mr. PELLATT, in his *Curiosities of Glass-making*, no pot could be moved from the spot where it was dried, to be placed in the annealing arch, without a notice in writing to the supervisor; a second notice was required for gauging; a third for setting it in the furnace; again, for filling the pot; and another for lading it out; whilst the maker was forced to comply strictly with the act of parliament, by giving the officer six hours' notice for each of these intricate and vexatious requirements.

Again, with reference to the subject of annealing, the same able writer remarks:—When the excise upon glass existed, the hear was secured by fastenings and locks—supplied by the Government officer at the expense of the trader, and safely secured every Friday or Saturday, and not re-opened till the Monday following. During the whole of the week, the officer had the surveillance of the hear, but especially of the sorting-room, at the delivery end of the hear, which was only entered at the stipulated act of parliament periods. If a link forming part of the endless chain running under the hear, connected with the machinery drawing down the pans, accidentally broke in the night, and the officer should happen to be absent—which was rather the rule than the exception—either the whole works must be stopped, or some mode adopted for the hearman to repair the mischief not strictly in keeping with the act; so that while the principal was quietly reposing in his bed in imaginary security, his servant, unknown to him, had almost necessarily incurred ruinous excise penalties. The excise officer gauged the liquid glass in the pots, which he had the option of charging by weight, at a specific gravity of 32·00; and should the manufactured annealed goods ultimately not amount to two-fifths of that estimate, he had to pay the difference. The hear charge was always considered to be the chief security, as indeed it really was; still, with the utmost excise vigilance, the trader occasionally defrauded; but owing to the great heat of the arch, and the usual excise securities, the revenue was, on the whole, well secured at the hears. Had the hears or kiln been the only departments of the works under excise survey, the manufacturer would not have been so much inconvenienced. The surveillance of the pots was his chief annoyance, since it required endless trouble, and subjected the manufacturer to danger of exchequer prosecutions. To throw into the pots over so small a piece of metal, during the working, incurred a penalty of fifty pounds for every offence. Neither plate-glass nor bottle-glass manufacturers were subject to the surveillance of the pots: this made it exclusively injurious to the flint-glass maker, and was

almost a prohibition of alteration of tint, or experiments, and consequent improvements. It is matter of astonishment how flint-glass works existed at all, under such a concentration of commercial and manufacturing hindrances as were imposed by the excise regulations; happily, the incubus exists only in reminiscence.

While the greatest stimulus was given to the crown and sheet glass manufacture by the abolition of the duty in 1845, that abolition has produced a somewhat paradoxical result, which is thus stated by Mr. HENRY CHANCE:—While the quantity of glass made has increased in the proportion of three to one, the number of manufacturing firms has diminished in the proportion of one to two. In 1844 there were fourteen companies engaged in the manufacture. In 1846 and 1847, following the repeal of the duty, the number had increased to twenty-four. The glass trade, after the removal of the heavy burden imposed upon it, seemed to offer a fair opening for money seeking investment. The demand for glass was so great that the manufacturers were in despair. Glass-houses sprung up like mushrooms. Joint-stock companies were established to satisfy the universal craving for window panes. And what was the result? Of the four-and-twenty companies existing in the year 1847, there were left, in 1854, but ten. At this time there are but seven in the whole United Kingdom. Two, established in Ireland, have ceased to exist. In Scotland, the Dumbarton works, once famous, were closed in 1831, by the death of the partners, afterwards re-opened, and again closed. The seven now existing are all English.

While thus diminished in number, the immense extent and resources of the principal great glass-houses now existing may be inferred from the fact already alluded to, namely, that the firm of CHANCE and Company executed the large order in sheet-glass for the Great Exhibition structure of 1851 without materially affecting their power of executing their general orders. In such immense establishments, experiments, now untrammelled by the meddling officiousness of an absurd legislation, can be executed on a large scale, and vast improvements have been effected. Minute, and apparently unimportant changes, perceptible only to those near at hand, have in silence done their work.

Still, as one of the eminent members of the firm above referred to remarks, the development both of the processes and applications of the glass manufacture is incomplete. Sir JOSEPH PAXTON's glass arcade, stretching over the streets of London, and Dr. SLEIGHT's city of glass, in which invalids will inhale the gentle air of Madeira,—these are faint foreshadowings of the destiny of this wonderful substance. And, perhaps, the day may come when some future chronicler of glass shall smile at the barbarians of the nineteenth century, who could not make window-glass without defects, and shall exhibit those defects as the curiosities of a by-gone age.

The annexed table, from MACCULLOCH, shows the state of the manufacture, quantity exported, and amount of duties, a few years previous to their repeal:—

I. Account exhibiting the Quantities of the different descriptions of Glass manufactured during each of the Three Years ending with 1842, with the Quantities exported, the Rates and Produce of the Duties, *et cetera*.

Description of Glass	Quantity manufactured	Quantity exported	Rate of Duty	Gross Amount of Duty.	Drawback on Glass exported.	Nett Amount of Duty (Excess, after deducting drawback and other legal allow- ances)
	Cwts.	Cwts.		£	£	£
Flint-Glass. 1840	104,880	19,913	{ To 15th May, 1840, 18s. 8d. } { per cwt.; since, 18s. 8d. per } { cwt. and 5 per cent. }	101,029	21,199	79,830
Ditto, 1841	97,524	20,516		95,565	22,605	72,960
Ditto, 1842	83,653	13,696		81,973	15,098	66,875
		Sq. feet.				
Plate-glass, 1840	33,623	52,879	{ To 15th May, 1840, £3 per } { cwt.; since, £3 per cwt. and } { 5 per cent. }	104,117	7,412	96,705
Ditto, 1841	27,639	121,113		87,061	17,483	69,578
Ditto, 1842	21,528	68,318		67,812	9,866	57,946
		Cwts.				
Crown-glass, 1840	129,978	15,318	{ To 15th May, 1840, £3 13s. 6d. } { per cwt.; since, £3 13s. 6d. } { per cwt. and 5 per cent. }	492,962	73,530	417,497
Ditto, 1841	116,895	19,118		451,064	92,070	357,337
Ditto, 1842	97,495	12,369		376,205	60,891	313,323
German sheet-glass, 1840	16,859	8,219	{ To 15th May, 1840, £3 13s. 6d. } { per cwt.; since, £3 13s. 6d. } { per cwt. and 5 per cent. }	63,986	33,604	30,382
Ditto, 1841	20,855	8,781		80,473	36,876	43,597
Ditto, 1842	25,500	7,701		98,397	32,348	66,049
			To 15th May, 1840, £1 10s.			
Broad sheet-glass, .. 1840	9,051	1½	per cwt.	13,915	2	13,913
Ditto, 1841			{ To 15th Aug. 1840, £1 10s. per cwt. and 5 per cent.; } { since, £3 13s. 6d. per cwt. and 5 per cent. }			
Ditto, 1842						
Common bottle-glass, 1840	525,574	292,887	{ To 15th May, 1840, 7s. per } { cwt.; since, 7s. per cwt. and } { 5 per cent. }	189,883	103,926	85,957
Ditto, 1841	501,177	310,937		184,174	114,109	70,065
Ditto, 1842	390,482	225,633		143,496	82,915	60,581
Total nett revenue collected during the three years ending with 1842,						£1,902,595
Annual average nett revenue of the three years ending with 1842,						£ 634,198

All kinds of glass may now be imported free of duty, except flint cut glass, flint colored glass, and fancy ornamental glass of every description, on which there remains a customs' duty of ten shillings the hundred-

weight. The residuary customs' duty of one shilling and sixpence a hundredweight on shades and cylinders, and any kind of window-glass, white, or stained of one color only, expired on the 5th April, 1857.

II. A return of the Rates of Duty on Glass in 1813, with the Quantities of each Kind of Glass retained for Home Use, and the aggregate Nett Revenue in each Year, from 1813 to 1842, both included, noting the Periods when any Alteration of the Duty took place, and the Amount of such Alterations.

Rate of duty in 1813, Per cwt.	Flint.	Plate.	Crown.	German sheet.	Broad.	Common bottle.	Total.	Period and amount of alteration of duty.	Aggregate nett revenue.
	98s.	98s.	73s. 6d.	73s. 6d.	80s.	8s. 2d.			
Years.	Quantities of glass retained for home use.								
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.		£
1813	23,370	9,398	84,441	..	6,994	47,350	171,553		500,850
1814	24,227	6,778	84,251	..	8,628	140,252	264,136		530,791
1815	24,911	419	77,485	..	8,452	129,461	240,728		479,780
1816	20,011	..	56,151	..	6,140	160,221	242,523		353,188
1817	22,117	1,739	76,561	..	8,374	123,881	232,692		461,849
1818	26,978	6,391	88,893	..	8,319	201,795	332,376		584,399
1819	28,809	6,473	90,726	..	8,267	238,463	372,738	{ From 5th July, 1819, the duty on plate-glass reduced from £4 18s. to £3 per cwt. }	606,176
1820	24,745	8,735	74,183	..	7,782	171,495	286,940		500,595
1821	21,927	9,718	86,384	..	8,085	137,117	263,181		521,075
1822	21,400	9,562	95,510	..	8,353	154,492	289,317		559,029
1823	21,829	11,607	101,392	..	9,172	198,456	342,456		607,378
1824	24,951	13,543	123,845	..	9,295	238,725	410,362		728,342
1825	34,184	15,082	140,298	..	8,347	251,932	449,843	{ From 5th July, 1825, the duty of £4 18s. on flint-glass repealed, and a new duty of £12 10s. for every one thousand pounds of fluxed materials for flint-glass imposed. }	772,303
1826	47,090	12,527	115,731	..	8,113	282,512	465,973		720,920
1827	46,688	14,209	114,381	..	7,611	239,794	422,683		699,726
1828	54,255	17,096	121,158	..	6,970	254,787	454,266	{ From 5th July, 1828, the duty on common bottle-glass reduced in Great Britain from 8s. 2d. to 7s. per cwt., and the duty on every description of glass assimilated throughout the United Kingdom. }	752,097
1829	50,869	13,925	92,252	..	6,864	218,901	382,811		609,406
1830	49,353	12,677	80,926	..	4,845	180,945	328,746		542,261
1831	49,608	14,373	88,688	..	5,915	150,520	299,104		531,718
1832	51,586	11,554	86,007	179	5,304	158,719	313,349	{ From 10th October, 1832, the duty on fluxed materials for flint-glass reduced from £12 10s. per one thousand pounds to 20s. for every one hundred pounds. }	558,423
1833	51,818	13,893	105,134	..	6,306	164,000	344,151		645,781
1834	52,890	16,306	106,389	..	6,766	194,143	376,494		664,391
1835	43,936	16,941	111,651	4,218	5,847	201,613	384,236	{ From 10th October, 1835, the duty on fluxed materials for flint-glass reduced from 20s. to 6s. 8d. per one hundred pounds. }	640,149
1836	86,866	19,993	117,041	..	7,629	249,145	480,674		663,162
1837	78,121	21,640	101,309	707	7,190	247,446	456,413		608,993
1838	81,594	23,992	113,756	2,262	6,575	243,046	471,225		667,998
1839	82,309	26,465	113,340	5,170	8,514	252,808	488,606		691,467
1840	82,486	31,200	111,316	7,914	9,049	232,831	473,799	{ From 15th May, 1840, the duty on every description of glass increased 5 per cent.; and from 15th August, 1840, the duty on broad glass increased from £1 10s. to £3 13s. 6d. per cwt. }	724,343
1841	74,444	22,088	93,033	11,298	..	190,257	391,120		613,588
1842	68,098	18,396	81,715	17,117	..	161,537	346,963		563,437

The following tabular statement, exhibiting the amount of the imports of the different kinds of glass enumerated, for the three years ending 31st December,

1855, and the exports of glass, of *foreign and colonial manufacture*, during the same period, is extracted from the Trade and Navigation Returns:—

	IMPORTS.			EXPORTS.		
	1853.	1854.	1855.	1853.	1854.	1855.
Window-Glass, and Shades and Cylinders,.... Cwts.	27,577	31,639	25,420	5,485	3,012	1,126
Plate-Glass,..... Lbs.	221,304	794,191	749,151	16,415	14,175	21,747
White Flint-glass Goods—except bottles—not cut, engraved, or otherwise ornamented,.... Lbs.	106,621	358,472	378,065	15,980	4,584	3,039
All Flint Cut Glass, Flint Colored Glass, and Fancy Ornamented Glass,..... Cwts.	6,893	10,692	9,402	1,143	846	585

The above exports refer to glass of foreign and colonial manufacture. The great falling off in these exports during the years 1854 and 1855, is obviously attrib-

able to the war with Russia; but this effect scarcely appears in the following statement of the exports and declared value of glass of *British manufacture*:—

	Hundredweights exported.			Declared value.		
	1853.	1854.	1855.	1853.	1854.	1855.
Flint-Glass,	47,548	53,072	39,283	£162,849	180,896	141,831
Window-Glass,	39,158	34,522	21,473	58,503	57,761	33,821
Bottles,	457,787	481,262	513,128	248,458	274,832	279,620
Plate-Glass—value only,				48,730	35,755	52,283
				£518,540	£549,244	£507,555

It is worthy of remark, that in the year 1844, the year before the excise duties were repealed, and with all the advantage of a drawback, the total exports of glass, of British manufacture, were only of the declared value of twenty-six thousand six hundred and ninety-four pounds; whereas, it will be seen from the preceding table, that in 1855, or ten years after the repeal of the duties, they amounted in value to upwards of half a million sterling.

GLYCERIN.—The basic principle of the several substances contained in the fats of animals, as also of several compounds of vegetal origin, has been called *glycerin*. SCHEELÉ, its first discoverer, named it *the sweet principle of fat*; but since then, the several investigators who have worked upon the subject have modified this title to that above given, from the Greek word, signifying *sweet*. As already noticed—see vol. i., page 406—this body has not as yet been fully investigated, and considerable diversity of opinion exists regarding its origin and nature. It is generally acknowledged to be an oxide of a compound radical, which, upon the decomposition of the stearin, margarin, or olein of the fats, assimilates water, and acquires the composition which analysis has assigned to glycerin. Respecting the nature of this radical, much speculative reasoning has been indulged in. BERZELIUS designated it *lypyl*, and contended that the definite bodies in the natural fats were salts of the fatty acids, with the oxide of this radical. LÖWIG, on the contrary, with whom many concur, terms it *glycil*; all, however, seem to have attributed to it the composition $C_3 H_9$, and agree that, by the assimilation of oxygen and the elements of water, it becomes $C_6 H_8 O_6 = 2 (C_3 H_2) + O_2 + 4 HO$.

PREPARATION AND PROPERTIES.—Originally, glycerin was prepared by a rather troublesome process, and necessarily in small quantity. Olive oil, or any of the natural fats, was boiled with litharge—oxide of lead—and water, till saponification was effected; the fluid matter remaining was decanted, and submitted to the action of sulphide of hydrogen— HS —by which the portion of the metallic base held in solution was precipitated in the form of sulphide. After filtration, the liquid was exposed to careful evaporation under 212° , till all the water was removed, and a viscous fluid remained. This was the glycerin. Prepared so, it is a faintly yellowish fluid, with an agreeable sweet taste; it is soluble in water, which it attracts from the air, and likewise in alcohol, but not in ether. The alkalies, and several metallic oxides and salts, more especially those which are known to deliquesce in the air, are dissolved by it to such an extent that it ranks next to water in solvent power. With acids it invariably yields acid salts. It is a very stable compound, being persistent in air; it suffers partial decomposition when slowly distilled, and passes over unchanged when a temperature of from 500° to

600° is applied; but, when subjected to a heat beyond this, it is entirely transformed into another definite body, known as *acrolein*, acetic acid, and inflammable gases. Thrown upon live coals, or heated in contact with air, it burns with a blue flame; heated with phosphorus in a closed tube, it yields acrolein.

When largely diluted with water and mixed with yeast, after long standing at a temperature between 68° and 85° , it yields, according to REDTENBACHER, a small quantity of gas and metacetic or propionic acid— $C_6 H_5 O_3 = C_6 H_8 O_6$, minus three equivalents of water.

DOBEREINER found that, by the action of spongy platinum, it was converted into an acid. Concentrated nitric acid transforms it into water, carbonic, and oxalic acids; and, by operating upon it with hydrochloric acid and binoxide of manganese, formic acid is produced by cautiously treating it with dilute sulphuric acid. VOGEL states that it may be converted into glucose, which requires confirmation, for the tendency is for both to unite and form an acid salt. PELOUZE found this to be the case; for on mixing one part of concentrated sulphuric acid with half a part of glycerin, much heat was developed, and glyccero-sulphuric acid resulted, the formula of which was ascertained to be $C_6 H_7 O_6 SO_3, HIO SO_3$.

Glycerin is heavier than water, being at 59° of the density 1.28; its composition, deduced from the analyses of itself and its salts by PELOUZE, is:—

		Centesimally
6 Eqs. of Carbon,	36	39.130
7 Eqs. of Hydrogen,	7	7.609
5 Eqs. of Oxygen,	40	43.478
1 Eq. of Water,	9	9.783
	92	100.000



Until the late investigations of BERTHOLLET it was believed that glycerin was incapable of forming neutral compounds with acids; but from these researches it is evident that such a supposition can no longer be entertained, since synthetically the above-named eminent chemist produced compounds in every respect identical with the natural fats both of animal and vegetal origin, by the union of the respective acids of such bodies with glycerin. He found that this base is capable of uniting with one, two, or three equivalents of the acids respectively, the triacid body being similar in all its properties to the natural fat of which such acid may be a component. The several compounds are prepared by heating the acid and glycerin together, during three or four days, in close vessels, at 212° ; or for as many hours, at a temperature varying from 360° to about 500° , employing an excess of one or other of the constituents, according as the mono-di- or tri-acid compound is to be produced. By treating the mixture of

fatty acid and glycerin with hydrochloric, sulphuric, phosphoric, or tartaric acid, in a close vessel, for some hours, at the boiling point of water, the same results are obtained. These several formations are attended with the separation of the elements of water, which, however, does not take place in proportion to the equivalent

of acid which combines with the glycerin, though the analogous compounds of each of the fatty acids correspond in this respect. This disposition of the bodies will be better understood by collating the symbols of the several fats and their constituents, as in the following:—

Monostearin,.....	$C_{42} H_{82} O_8$	$=$	$C_{36} H_{70} O_4$	$+$	$C_6 H_8 O_2$	$-$	$2 H_2O$
Bistearin,.....	$C_{78} H_{154} O_{12}$	$=$	$2 (C_{36} H_{70} O_4)$	$+$	$C_6 H_8 O_2$	$-$	$2 H_2O$
Tri or Ter-stearin,.....	$C_{114} H_{214} O_{12}$	$=$	$3 (C_{36} H_{70} O_4)$	$+$	$C_6 H_8 O_2$	$-$	$6 H_2O$
Monomargarin,.....	$C_{40} H_{80} O_8$	$=$	$C_{34} H_{64} O_4$	$+$	$C_6 H_8 O_2$	$-$	$2 H_2O$
Bimargarin,.....	$C_{76} H_{146} O_{12}$	$=$	$2 (C_{34} H_{64} O_4)$	$+$	$C_6 H_8 O_2$	$-$	$2 H_2O$
Trimargarin,.....	$C_{108} H_{204} O_{12}$	$=$	$3 (C_{34} H_{64} O_4)$	$+$	$C_6 H_8 O_2$	$-$	$6 H_2O$
Monolein,.....	$C_{42} H_{80} O_8$	$=$	$C_{36} H_{64} O_4$	$+$	$C_6 H_8 O_2$	$-$	$2 H_2O$
Biolein,.....	$C_{78} H_{150} O_{12}$	$=$	$2 (C_{36} H_{64} O_4)$	$+$	$C_6 H_8 O_2$	$-$	$2 H_2O$
Triolein,.....	$C_{114} H_{210} O_{12}$	$=$	$3 (C_{36} H_{64} O_4)$	$+$	$C_6 H_8 O_2$	$-$	$6 H_2O$

Until within the last few years, glycerin was invested only with scientific interest, and its production was of rare occurrence; now, however, it has acquired considerable repute, and is manufactured in large quantities. In medicine it is calculated to render very great services as a vehicle for exhibiting the various remedies, besides being itself a specific for many ailments. Under certain circumstances, it acts as a valuable antiseptic, and a solvent in the cure of many kinds of urinary calculi. In perfumery and cosmetics its use is daily extending, being, on account of its emollient qualities and freedom from greasiness, an admirable ingredient for soaps, pomade, hair tonic, *et cetera*. Photographers likewise have latterly employed it with success. In these and several other appliances it is likely that in a short time its consumption will be much greater than at present, although it has already been manufactured extensively.

Several modified processes are pursued to obtain it, some of which may be briefly noticed. As already stated, it was procured as a secondary product in the manufacture of lead plaster. Equal parts of powdered litharge and olive oil were mixed with water, and the mixture boiled till a plumbiferous soap resulted from the combination of the oleic and other fatty acids and metallic oxide. During the ebullition, the contents of the vessel were kept stirred, and water supplied from time to time, to make up the loss by evaporation. When the yellow color of the litharge disappeared, and the mass looked white and homogeneous, the fire was removed, and the liquid portion decanted, and afterwards treated with sulphide of hydrogen, as long as any precipitation occurred. A succeeding filtration removed the metallic sulphide, and after this the liquid was evaporated at a water-bath heat, and finally in an exhausted receiver over sulphuric acid. When the evaporation is performed in contact with the air, the fluid acquires a brownish tinge. JAUN'S process is similar to the foregoing, only that the proportion of the substances is varied. Instead of equal quantities, he takes five parts of litharge and nine of olive oil, and proceeds with them as described, and boils the soap with water three successive times, decanting and mixing the three solutions together. The tinge is removed by filtration through animal charcoal, or by digesting the weak

liquor with a mixture of animal and freshly-prepared wood or peat charcoal, filtering and concentrating in the usual way. By this course, he obtained about seven ounces of glycerin from the above quantity of materials. Glycerin can be obtained from the mother liquor of the soap factories, by adding to it a slight excess of sulphuric acid, heating the solution with carbonate of baryta, filtering, and, after the filtrate has been concentrated by evaporation, extracting the glycerin with alcohol. On distilling off the spirit, the glycerin remains. It may likewise be readily prepared by dissolving castor oil in absolute alcohol, and passing hydrochloric acid gas through the fluid. The fatty ethers are washed away by water, and the residuary fluid affords the glycerin in a state of purity on evaporation. Any adhering fatty matter is separated by digesting the liquid in ether, and decanting the latter.

CAP'S process for the preparation of glycerin from the mother waters of the saponification of stearin with lime in the manufacture of stearic acid candles, is as follows:—The liquid drawn off from the lime-soap is reduced by evaporation in steam kettles over a naked fire; and, after ascertaining how much lime is present, by precipitating a certain bulk with oxalate of ammonia, collecting the precipitate, drying, burning, and weighing it, with the requisite precautions, the necessary quantity of sulphuric acid to combine with the lime is added, when sulphate of lime falls.

After its subsidence, the clear liquid is decanted into another receptacle, in which it is boiled out of contact with the air, and stirred at the same time by some mechanical arrangement. This ebullition expels all the volatile fatty impurities which may be present, and, consequently, the liquid loses both color and odor. As soon as the solution arrives at a density of 14° Twaddell, it is allowed to cool, when the precipitation of a further portion of sulphate of lime occurs. Should an excess of acid be present, as may be known by its action on tincture of litmus, some chalk or powdered limestone must be added fractionally till the liquid is neutral. After this the boiling is continued as before out of contact with air, during which time the contents of the vessel must be actively stirred, till the solution marks 37.5° Twaddell. The sulphate and carbonate of lime are now collected on a filter, and the filtrate reduced by evaporation, till, upon cooling, it marks 49°, care

being taken to keep it well agitated during the time. If any further quantity of sulphate of lime falls, a repetition of the filtration is necessary. To remove the tinge, the fluid is passed through washed animal charcoal or bone black, when a pure colorless solution of glycerin is obtained, marking 45° ; and, by carefully concentrating it further, a fourth of its weight of water may be removed, when the residuary sirupy fluid indicates 51.2° Twaddell. According to WILSON, the product thus obtained, though superior to that manufactured by the old process, is not absolutely pure, no matter how much care is taken in conducting the operations.

A much more economical method is that introduced by TILGHMANN in 1854. By this process the fatty bodies are broken up into acid and basic substances, through the agency of heat, pressure, and steam, as described at page 433, vol. i., and form separate layers in the recipient, into which the products flow from the condenser. The glycerin, which is the heavier of the two, forms the lower stratum, and the fatty acids the upper; the latter can be readily separated mechanically, and the former left devoid of any other impurity excepting water. By careful concentration, the aqueous matter may be expelled, and the product obtained of a specific gravity of 1.24, and containing only four per cent. of moisture; but, by prolonging the operation, two per cent. more of water may be removed, and the pure glycerin is left of a density = 1.260. WILSON, by injecting superheated steam into a hot solution of fat, succeeded in effecting the decomposition of the latter, and at the same time the fatty acid and glycerin are carried over into the receiver, where they form two layers, as in the preceding instance, and capable of being readily separated.

ANALYSIS.—The analysis of glycerin demands all the expertness of the practical chemist. It may be accomplished by submitting it, or some one of its more definite and permanent salts, to combustion with oxide of copper or chromate of lead. If a salt of this base with baryta or lime be the subject, it may be mixed with the powdered oxidizing agent, introduced into the combustion tube, and burned in the usual way; but when glycerin *per se* is to be analysed, it must be inserted into small glass bulbs, the apertures of which are drawn out to a fine point, and two or three of the latter introduced into the combustion tube, placing three or four inches of the oxidizing agent between them. From five to ten grains will be sufficient for the analysis. Attention should be paid to inserting the bulbs, so that the aperture of each may open towards the sealed end of the tube, in order that the fluid may have to traverse through a longer portion, and come in contact with more of the oxidizing agent than if the bulb part was dropped in first. By this means, a more thorough oxidation of the elements is insured. The water and carbonic acid produced during the burning are severally arrested by chloride of calcium and hydrate of potassa in the usual way, and their quantity determined. When operating upon liquid substances generally, the combustion tube should be longer than when required for solid bodies, to present a greater oxidizing surface to the vapor as it passes off.

Glycerin cannot be readily detected in animal fluids, unless it be present in such quantity as will permit its being extracted and subjected to an elementary analysis; but as it is exceedingly difficult, or nearly impossible, to isolate it pure when associated with other animal matters, this method can rarely be successful. A characteristic test remains, however, whereby the presence of glycerin may be ascertained, in the peculiar bodies to which it resolves itself on being decomposed by heat. The most remarkable of these is acrolein—a substance possessing such an intense and marked odor as to render it unmistakeable. When, therefore, the substance suspected as glycerin, after being deprived as far as possible of all impurities, is rapidly heated either *per se* or with a little anhydrous phosphoric acid, an acrid pungent odor, somewhat analogous to that of the wick of an extinguished candle, is evolved, and this is sufficient proof of the presence of glycerin.

GOLD.—*Or*, French; *Gold*, German; *Aurum*, Latin.—This most precious of the metals, so highly esteemed on account of its rarity, beauty, high specific gravity, non-liability to tarnish or oxidize, and consequent admirable adaptation, both as a medium of exchange, and for articles of ornament, has been known and prized from the most remote antiquity. In its pure state, it is of a rich yellow color, high metallic lustre, but nearly as soft as lead, so that it cannot be used in a state of absolute purity either for jewellery or coinage. It is the most malleable of metals, and with the single exception of platinum, it is the heaviest body in nature, being nearly twenty times the weight of its bulk in water. Gold is almost always found in the metallic state, and in this form is largely diffused over the earth; but in many localities it occurs in such minute and widely-scattered fragments, that it will not pay for working expenses. It is found in many forms—in masses, lumps, fragments or nuggets, dendritical threads, scales, dust, and infinitesimally mixed with the auriferous quartz; but almost always mechanically mixed, and not chemically, as with other metallic ores. Hence, the operations for extracting it from its deposits differ from those required by almost every other metal, in being for the most part purely mechanical. They chiefly consist in pulverization and washing—the high specific gravity of the metal greatly facilitating the latter process. But thoroughly to extract the gold, amalgamation is often resorted to—a quantity of mercury being mixed with the ore, which forms an amalgam with the gold, and is afterwards expelled by distillation. If copper and silver be present, which is generally the case, the former is removed by cupellation, and the latter by a process termed *parting*. These operations will be fully described under their proper heads. They have merely been referred to at present to explain the incidental allusions to the metallurgical department of the subject, which cannot be entirely avoided in detailing the history of the metal, and of modern gold discoveries.

HISTORICAL NOTICE.—From the circumstance that gold occurs in the metallic state, often mixed with the superficial soil and sands of rivers, it was probably the first of the metals known to man. Accordingly, one learns from the sacred record, that gold existed in that

part of the earth's surface which was first prepared as the dwelling of the human race. MOSES states, that the land of Havilah, encompassed by one of the four rivers which watered the garden of Eden, not only possessed gold, but gold of a superior quality; and JOB, who is supposed to have written about 1800 years before the Christian era, alludes to the earth having *dust of gold*. With reference to the remark of MOSES, that the gold of the land of Havilah was good, Mr. NAPIER of Glasgow, in a recent publication on the Ancient Workers and Artificers of Metals, justly regards it as warranting two inferences; first, that gold had been found in other localities than the one referred to; and, second, that different qualities of gold were known in the time of MOSES. But as this, like the other metals, is an elementary substance, and not a compound, it follows that all gold, when pure, must be of the same quality. Hence the further inference, that the workers in metal in the time of MOSES, with all the acknowledged skill of the ancients in metallurgy, were not acquainted with the method of reducing gold to a state of absolute purity. That they were acquainted with the refining of the precious metals to a certain extent, plainly appears from different passages in the Old Testament, in which familiar allusion is made to this operation; and made, too, in terms which seem to imply that the methods then adopted were in many respects similar to those now employed. Silver and gold are purified or separated from foreign ingredients by much the same processes; a knowledge of the one implies a knowledge of the other; and JOB says, surely there is a mine for silver, and a place for gold, which men refine; while DAVID compares the words of the LORD to silver tried in a furnace of earth, purified many times. MALACHI is still more particular when, in comparing the Judge of all the earth to a refiner's fire, he says: *he shall sit as a refiner and purifier of silver, and he shall purify the sons of Levi, and cleanse them as gold and silver*. Here there is an evident allusion to the last operation required in the refining of silver—that of *cupellation*—during which the refiner must place himself at the furnace, and watch till the metal emits a bright flash, which indicates that the process is finished. Gold, as will be afterwards explained, is submitted to the same operation; but it requires a further treatment to free it from the silver with which it is invariably mixed to a greater or less extent; and this operation, known as *parting*, is the only process, essential to the perfect purification of gold, which does not seem to have been known to the ancients. There is, at least, no evidence that they were acquainted with this process; but rather the contrary, from the words of MOSES, which indicate that gold from a variety of sources was then believed to possess essentially different qualities; although, it is true, that the sacred historian may refer to the different states of purity in which the metal was found.

The small per centage of silver which is frequently found in gold in the native state, detracts but little from its bounty or value; and as the ancients appear to have been well acquainted with the methods of separating it from other ingredients, there is little doubt that a large proportion of their gold approached to a state of purity. On the other hand, it is frequently

found combined, or mechanically mixed, with a very considerable amount of silver; and hence it may be presumed, that much of the gold in circulation among the ancients, was merely an alloy of these two metals in those proportions in which they are found in nature. This view of the subject is not only rendered probable by the frequent allusions to *fine gold*, and to gold of different qualities obtained from certain specified sources, such as the gold of Ophir, gold of Parvaim, gold from the north, *et cetera*; but it is confirmed by the fact, that the ancients had a special name for the alloy produced by the mixture. This alloy they termed *electrum*, which PLINY states to have been made artificially by mixing four parts of gold and one of silver. Now, it is worthy of notice, that this is about the mean proportion in which the admixture is found native in many auriferous localities; and hence it may be presumed, that the alloy termed *electrum*, for which the moderns have no distinguishing name, was formed by the ancients artificially to imitate a large proportion of the gold which was then in circulation, separated from all its native impurities, except the silver. BECKMANN, who states positively that the ancients were not acquainted with the art of separating gold and silver, affirms that they used the *electrum* as a peculiar metal; and NAPIER is at the pains to argue, that since they made it artificially, it could not have been considered by them a distinct metal. But BECKMANN evidently means that they regarded the mixture in the same light as brass, bronze, German silver, and other useful alloys are viewed in the present day.

On the whole, there is strong ground for believing that the ancients were unacquainted with the method of *parting* these noble metals—the difficulty arising from the fact, that both of them refuse to be oxidized in the furnace; and yet, there is a shade of doubt on the subject, which renders it peculiarly interesting to the archaeologist. Nitric acid is said to have been unknown until it was discovered by the alchemists in the thirteenth century; and yet, Mr. HERAPATH, of Bristol, has lately discovered that the markings on a piece of mummy cloth were made with a solution of silver, which he concludes to have been the nitrate, or common marking ink. Indeed, there is some ground for believing that the ancient Egyptians were acquainted with both nitric and sulphuric acids, with either of which the operation of *parting* is performed; and in that case, they could not be ignorant of the fact that nitric acid dissolves silver, and that it is without effect upon gold. On the other hand, it is difficult to suppose, that if these things were known to the Egyptians, they should not have been known to other nations, and more especially to the Hebrews.

But whatever doubt may rest on this point, it is certain that the ancients, in later times at least, were acquainted with the method of extracting gold and silver from the ores or earths by *amalgamation*, for this process is mentioned both by VITRUVIUS and PLINY, writers who lived about the beginning of the Christian era; and, indeed, it is described by PLINY in terms which show that it was practised nearly in the same manner as at the present day. The mercury employed in this operation, merely combines with the

metals in the earths with which it is mixed, and these must afterwards be separated by other processes.

Both gold and silver, more or less pure, were used by the ancients for articles of ornament and utility, as well as for money. Many of the vessels, and much of the sacred furniture of SOLOMON'S magnificent temple, were made of gold. It is stated also, that in forming the tabernacle in the wilderness, gold was beat into thin plates, and cut into wires or threads to work it in the fine linen, from which it appears that the Israelites had learned from their masters, the Egyptians, the art of gold-beating—an art in which, WILKINS states, in his *Ancient Egypt*, the latter were well skilled.

Gold was also in great demand among the heathens, for the statues of their gods or idols; and some of these are mentioned by HERODOTUS and other historians as of immense magnitude. In connection with this subject, the golden calf which was made by AARON in the wilderness, has furnished a curious subject of controversy to modern commentators. With reference to this object of idolatrous worship, it is recorded that MOSES took the calf, and burned it with fire, and ground it to powder, and strowed it upon the water, and made the children of Israel drink of it. In another passage it is stated, that he stamped it, and ground it very small, even until it was as small as dust. Now, the difficulty connected with this passage, which has so much perplexed well-meaning commentators, is the fact, that gold, however strongly heated, is incapable of being reduced to powder by mere stamping or grinding. It is, as already stated, the most malleable of the metals, and is only *flattened* by stamping. Hence it has been affirmed by Dr. KIRRO, on the authority of GOGUET, and reiterated by other commentators as a great discovery, that MOSES was acquainted with the wonderful powers of *natron* as a solvent of gold, and that the golden calf was either burned with *natron*, or was heated in the fire to accelerate the action of that solvent. Unfortunately, however, it so happens that *natron* or carbonate of soda has no such action upon gold as that which is ignorantly attributed to it by these writers; moreover, there is no mention of any solvent being used, or of any intention on the part of MOSES to communicate to the water with which the gold was mixed a nauseous taste, though this appears to be the principal object of the commentators. In fact, as NAPIER justly remarks, the whole chemical or metallurgical difficulty, if any such exists, may be got over, by merely assuming that MOSES fused the gold in the fire to cast it into ingots, which were afterwards beat out into thin plates or leaves, and then would readily admit of being reduced to powder—a process which is practised at the present day to procure an impalpable gold dust employed for various purposes.

Although it can scarcely be supposed that the total amount of gold in circulation in ancient times was so great as at present, yet, from the practice of hoarding the precious metals which then prevailed, and from the limited commercial intercourse which then existed, it seems to have accumulated in some countries, and in particular circumstances, to an incredible extent. Conquerors were accustomed to carry off all the gold they could collect or extort from the subdued nations;

and thus, after a series of successes, the coffers of the victorious monarch and his subjects became replenished with treasure. Hence the vast amount of the precious metals which poured into Rome from the provinces, when she ruled the world. Hence also the enormous accumulation of gold and silver which King DAVID is recorded to have collected during his lifetime for building the temple—an amount which has been estimated at not less than nine hundred million pounds sterling, being more than all that has been raised in all the mines in the known world during the last fifty years. It is scarcely possible to avoid the suspicion that some error has crept into the calculations by which this astounding result is arrived at; but still it is quite certain that immense quantities both of gold and silver were often accumulated in ancient times; and to this day no inconsiderable mystery hangs over the sources from which these treasures were derived. Any little knowledge that is possessed on this subject will be mentioned in enumerating the auriferous or gold-producing localities known at the present day.

It is probable that with the decline of the Roman Empire, the art of extracting and refining the precious metals, like other arts, became to a great extent lost in the darkness of mediæval barbarism. It was then, however, that a new art began to appear, which aimed at a still higher object, and which, however chimerical in its pursuits, struck out many important incidental discoveries, and contributed largely to prepare the way for the triumphs of modern chemistry. Any account of the history of gold would be incomplete which did not make some allusion to Alchemy—the chemistry of the middle ages—by which was elaborated, not gold indeed, but much of the apparatus and many of the principles of a science which is infinitely more important to the human race than gold itself. The object of alchemy was not the refining of the precious metals, but their multiplication, by the transmutation of the baser metals into gold and silver. This pursuit, which may be termed sordid, when viewed in the light of the motives by which it was animated, continued through long centuries of darkness to lead the philosophical world on an *ignis fatuus* chase, terminating in disappointment and misery. HERMES TRISMEGISTUS, who is said to have lived in the year of the world 2076, has generally been quoted as the oldest of the alchemists; but there can be little doubt that the writings attributed to him are entirely spurious. The next great name in the history of alchemy was GEBER the Arabian, who is supposed to have lived not later than the seventh century of the Christian era. A work on alchemy, in three books, bearing the name of this philosopher, was published at Strasburg in 1520, and shows a considerable knowledge of the chemical properties of gold. This metal was termed by the alchemists *Sol*, the sun—and silver, *Luna*, the moon. Medical preparations of gold were termed *solar*, and those of silver, *lunar* medicines. One of the chapters of the work attributed to GEBER is devoted to *The Alchemie of Sol*; and after descanting upon different means of refining and dissolving gold, the author describes several solar medicines, which are all solutions of gold in nitro-hydrochloric acid, with the addition of quicksilver or

mercury, common salt or chloride of sodium, and some other saline matters. If the work be genuine, therefore—a point, however, on which considerable doubt rests—nitro-hydrochloric acid was known as the solvent of gold in the seventh century. It was certainly known as such not later than the fifteenth, and was termed by the alchemists *aqua regia*, or the royal solvent, from the circumstance that gold was regarded by them as the king of metals. They esteemed it, indeed, the only pure metal, and believed that all the others were merely adulterations or diseased forms of the same substance, which might be purified or revived by proper processes. Mercury and *aqua regia* were the principal agents which they employed. Not a few of them pretended to have discovered the secret; and some were even so disinterested as to publish the process, but in language understood only by the adepts, and which, it may be safely presumed, was rarely intelligible to themselves. In all cases, the student was directed to prepare his mind by suitable acts of piety and charity; and much religious and cabalistic jargon was mixed with their pretended recipes. From the fact that, in the present state of chemical science, the other metals, as well as gold, are believed to be elementary substances, the Editor deems it unnecessary to say that the doctrine of transmutation was founded on ignorance; but at a time when the elementary nature of the metals was unknown, the belief in their possible transmutation was natural; hence it was cherished by not a few persons of acknowledged eminence. The celebrated ROGER BACON, who flourished in the thirteenth century, was a believer in alchemy, and published a work on the subject. VAN HELMONT acknowledges his belief in the making of gold and silver, though he does not degrade himself, like too many of his contemporaries, by professing to have discovered the secret. BERGMAN, in summing up the evidence for and against the possibility and probability of transmutation, arrives at the conclusion that, unless all historical evidence be rejected, some of the accounts given are entitled to confidence. Even the great Lord BACON has been arraigned as a believer in alchemy, though he rather urges the possibility than the probability of transmutation—a view of the subject so far from meriting ridicule that, in the state of chemical science in his day, it would have been unphilosophical to hold a different opinion. That BOYLE was a sceptic on the subject is well known; but it is less generally known, and in fact it has only lately come to light, that in the ranks of the alchemists must now be enrolled the illustrious name of Sir ISAAC NEWTON. This startling fact is a recent discovery, published for the first time in the last edition of Sir DAVID BREWSTER's life of that philosopher. It is now known that he was absorbed in this pursuit for years; and that the intense eagerness with which he prosecuted this object accounts, to a great extent, for the apparent indifference which he showed in so long delaying to publish some of his greatest discoveries. Associated with such an array of great names, and more especially with the last, the alchemists are not to be contemned or derided as mere dreamers and visionaries; the pursuit of the object which they had in view was as

natural as their belief in the possibility of its attainment was warranted by the knowledge of the composition of matter then existing; but that which excites a just indignation, which constitutes a fair subject for ridicule, and stamps with infamy many of the professors of the art, is the mixture of fraud, pretension, and hypocrisy, which appears in their writings. It is these unworthy professors that have brought contempt on a pursuit that was prosecuted by many good and great men; and which, however fruitless as regards the immediate object in view, elicited many important facts of which science at the present day reaps the full benefit. The history of alchemy—so replete with empiricism and pretension—teaches also the gratifying fact, that not only has the philosophical world advanced in knowledge, but in candor, in honesty, and in moral dignity.

The further history of gold, which has assumed a profound interest in modern times, and demands therefore a larger space than is usually devoted to historical notices in this work, will be given in connection with the sources or localities from which it is chiefly derived.

SOURCES.—With the single exception of iron, gold is more generally distributed than any other metal; but for the most part it occurs in such minute quantities, as either to escape notice, or, as already remarked, not to repay the cost of extraction. On the other hand, many localities in different quarters of the globe, and especially, of late years, portions of California and Australia, have proved splendid exceptions. The principal matrix of gold is quartz rock, and this rock is commonly a vein of greater or less thickness, intersecting beds of granite. The chief sources, however, from which gold is obtained, are the various alluvial deposits, consisting of sand and gravel, produced by the disintegration of silicious, granitic, and other igneous and metamorphic rocks, and which have been transported by the agency of water from the mountainous districts. In these beds it is invariably found in the metallic state, but is never quite pure; it usually contains a certain proportion of silver, and not unfrequently iron, copper, and small quantities of several other metals.

It is difficult, if not impossible, to ascertain the precise localities from which were procured the very considerable quantities of gold that indisputably existed in the earlier ages of the world. There is no doubt that many regions, now exhausted, would formerly yield large supplies of this precious metal. The name of the place which figures most prominently in the Old Testament writings, and which has reappeared as the designation of certain auriferous localities, in modern times, is the land of Ophir. This name occurs in the ancient book of Job, and is frequently alluded to afterwards in the Jewish history. It seems to have been the great source of gold in those days—the California or Australia of the ancient world; but in what country, or even in what quarter of the globe it was situated, is a problem not yet solved. It is certain that the Hebrews traded with it from the time of DAVID to that of JEROSAPHAT, and some have placed it in an island in the Red Sea; but this is inconsistent with the recorded fact, that SOLOMON's fleet took up three years in their voyage to Ophir, and brought home not only gold, but

apes, peacocks, spices, ivory, ebony, and almug-trees. Accordingly, others have removed it to Zanguebar, on the South-east coast of Africa; others have placed it about Guinea; some at Carthage; some have removed it to the East Indies; and others, still more fancifully, to Peru, or some other place in America. The only conclusion which may be safely drawn from this immense variety of conflicting conjectures is, that the question remains involved in uncertainty, although the most general and best supported opinion is that which identifies the ancient Ophir with the region of the modern Zanguebar.

HERODOTUS states that the people living near the source of the Indus, obtained a large quantity of gold from the eastern border of the great Bactriana, and the desert steppes of Cobi; and he also refers to productive mines in the North, the remains of which, on the South-eastern borders of the Ural mountains, are described by PALLAS in his Travels, and were likewise visited by LEPECHIN and GMELIN. These ruined mines, which have all the marks of a very remote antiquity, are supposed to have been the work of a nomadic people, in all probability the Scythians. It is evident that much gold was produced in ancient times from the mines of Nubia and Ethiopia, which, like those of the Uralian chain, produced a copper-yielding gold. BELZONI discovered that a very extensive tract had been worked in the Sahara mountains, and from these sources the PHARAONIS are supposed to have derived their wealth. Mr. JACOB, from a very close examination of the subject, is led to infer that not less than six million pounds sterling of the precious metal must have been produced annually from these mines.

There were rich silver mines in Attica; gold mines in Thrace, and in the island of Thasus. Thessaly produced ores which were rich in gold; and Epirus, rich silver mines. From these sources the Athenians drew their wealth.

The Romans obtained their treasures from various sources, besides the conquered provinces—from Upper Italy, the province of Aosta, the Noric Alps, Illyria. From this district, at one period, gold was abundantly obtained—partly in large grains on the surface, and partly in mines, so pure that an eighth part only was lost in the processes of smelting and refining. Its great quantity caused a decrease of one-third in the price through all Italy, and induced the proprietors to employ fewer workmen in order to raise the value. The Tarbelli, a people at the foot of the Pyrenees, also streamed extensively for gold.

It is stated on the authority of tradition, that when the Phœnicians visited Spain, they found silver in such abundance, that they not only loaded their ships to the water's edge, but made their common utensils, and even anchors, of this metal—a statement which harmonizes with the representations given by the Spanish discoverers of Peru. But whether this account be exaggerated or not, it is certain that the Phœnicians lost no time in taking possession of the country, and forming colonies in the present Andalusia. Now, it is known that Spain anciently possessed mines of gold in regular veins, especially in the province of Asturias. The Tagus and some other streams of that country were

said to roll over golden sands; and there is little doubt, that when colonized by an active commercial people like the Phœnicians, its mineral wealth would be developed, and would contribute largely to the supply of the precious metals in the ancient world.

It is affirmed, that the Romans extracted gold from the quartz lodes in Transylvania, and also at the Ofogan in Caermarthenshire in this island, during their occupation under Trajan. It is probable, however, that but little would be obtained from these sources; and not much further is known of the ancient gold workings.

The principal workings known at the present day are those of Australia, in the Southern hemisphere; of California, Mexico, and the Appalachian mountains, in North America; Brazil, Peru, and Chili, in South America; Kordofan and Sofala in Africa; the Ural mountains in Siberia; and Hungary in Europe. Gold is found, however, in smaller quantities in various other places; and the Editor will now briefly indicate the various localities in which it is known to exist, beginning with Europe, and concluding with the latest discoveries in Australia.

Europe.—There are probably few countries without traditions of gold, and these have not been wanting in the British Islands, which have furnished from time to time small quantities, although seldom in sufficient amount to be equivalent to the cost of procuring it. Specimens are occasionally found in Wales, in the Cornish stream-works, and in different parts of Devonshire; where mining operations were recently undertaken, but not with remunerative success. In Scotland, it occurs at Leadhills and Cumberhead in Lanarkshire, and Glen Turril in Perthshire, but only in very small quantities; although in the time of Queen Elizabeth, extensive washings for gold were carried on in the alluvial soil of Leadhills. In the county of Wicklow, in Ireland, a considerable quantity of native gold was discovered towards the close of the last century, disseminated in a quartzose and ferruginous sand. This gold was chiefly found in *pepitas* or solid pieces, one of which weighed twenty-two ounces; and so promising was the supply, that the peasantry in the neighborhood of Ballinacorney river actually gathered in the course of two months an amount of gold, for which ten thousand pounds sterling were paid. The extraction was then undertaken by Government; but the supply was soon exhausted, for during the two years that the mines were in operation, only nine hundred and forty-five ounces were obtained, which did not pay the necessary expenses, and the works were abandoned.

In France, the Rhone, and other rivers, present auriferous sands, but there are no workable mines in that country. It is probable that the deposits have been exhausted, like those of Spain, which were anciently rich and valuable, but are now neglected. So with the sands of the Danube, and many other European rivers, which still possess gold in small quantities, but rarely worth the expense of washing. In the valley of the Rhine, between Basle and Mannheim, for example, gold occurs in flakes mixed with titaniferous iron; but so minute are the spangles, that it takes from eleven hundred to fourteen hundred of them to weigh a grain, troy. There are also auriferous sands

in some rivers in Switzerland, such as the Reuss and the Aar.

In Sweden, there is a mine at Edefors in Smoland, where the gold occurs native, and also in auriferous pyrites. In Germany, no mine of gold has been worked, except in the territory of Salzburg, amid the chain of mountains which separates the Tyrol and Carinthia. In Piedmont, there are veins of auriferous pyrites in the gneiss rocks at the foot of Monte Rosa; and these, although they do not contain ten or eleven grains in a hundredweight of the ore, are stated to have long defrayed the expense of working them.

But the only gold mines of any importance in Europe, are those of Hungary and Transylvania; and these are not less remarkable for their position, than for the peculiar metals with which the gold is associated. The principal mines are those of Hungary, in which the operations are carried on in four distinct localities; first, at Königsberg, where the native gold is disseminated in ores of sulphide of silver, which occur in veins and small masses in a decomposing felspar rock, constituting a portion of the trachytic formation; second, at Borsan, Schemnitz; and third, at Felsobanya, in both of which the ores likewise consist of auriferous sulphide of silver; occurring, however, in veins of sienite and greenstone porphyry; fourth, and lastly, at Telkebanya, to the south of Kaschale, where the gold is extracted from a deposit of auriferous pyrites, amid trap-rocks of the most recent formation. The Hungarian gold mines do not appear to have been worked before the eighth century. In Transylvania, the gold occurs at different places in veins of carious quartz, ferriferous limestone, heavy spar, fluor spar, and sulphide of silver. These veins are often of great magnitude, averaging from six to ten, and sometimes extending to forty yards in thickness. In the mine of Kapnik, the gold is associated with orpiment in granite, and in those of Offenbanya, Nagy-Ag, and Zalatzna with tellurium, in a sienitic rock. The annual produce of Hungary is stated at two thousand eight hundred and ten pounds' weight, and valued at one hundred and seventy-six thousand pounds sterling.

It may be added, that the mines of Reichenstein, in Silesia, which had been abandoned for more than five centuries, have been recently opened with advantage, in consequence of the application, on a large scale, of a method invented by Professor PLATTNER, for separating gold from the waste of arsenical pyrites, which will be described afterwards.

Asia.—The gold mines of Russia, which are the most considerable in the old world, must come under the head of Asia, as they are situated partly on the eastern flank of the Ural mountains, and partly in the districts of Tomsk and Yeniseik in central Siberia. The Ural mines, including those of Berzovsk, near Ekaterinburg, extend through five or six degrees of latitude. Here there are deposits of partially decomposed auriferous pyrites disseminated in veins of quartz; and from these veins the valuable material is extracted by vertical shafts and lateral galleries. Generally, however, the gold is found associated with other metals, as platinum and palladium, in fragments or debris of

auriferous rocks, mixed or disseminated at some yards' depth in an argillaceous loam.

In the days of Pallas, the gold alluvia of Russia were supposed to exist only near Ekaterinburg; but, in the reigns of Paul and Alexander, they were found to extend through several degrees to the North and South of that locality. It was only in the reign of NICHOLAS that portions of the great eastern regions of Siberia were found to be highly auriferous. In these districts the ground rises into low ridges, similarly constructed to those of the Ural, and like them trending from north to south. They are offsets from the great east and west chain of the Altai, which separates Siberia from China. The amount of gold which is now extracted from these remote deposits far exceeds that obtained from the Ural, although, in the latter, sands of superior richness were discovered in 1842. This discovery was made by the removal of certain old buildings in which the washing operations had been carried on. Under the corner of one of the buildings, at the depth of three yards, a mass of gold was dug up weighing about eighty pounds English. This mass was placed in the collection of the Corps des Mines at St. Petersburg. The discovery of the rich sands was made at the same time; but in the Ural districts, the gold is not usually found in large lumps. It is commonly obtained in very small fragments, which are separated by washing; and the yield seldom exceeds thirty-six grains of gold per ton-weight of soil. In the Altai auriferous district, which is represented to be as large as France, not only is the gold found mixed with sand and gravel on the surface, but considerable quantities are extracted by pulverizing the rocks. It is a remarkable fact that, not many years ago, the gold obtained from this distant region did not amount to a third part of that which the Ural district produced, whereas, in 1843, the Eastern tract yielded considerably upwards of two millions and a quarter sterling, and the Ural little more than half a million, raising the total produce of the Russian empire to near three millions sterling. It now amounts to about four millions. In the century previous to 1841, the mines of Berzovsk yielded about twenty-four thousand five hundred pounds avoirdupois of the precious metals.

Little or no gold comes into Europe from other parts of Asia, because, as Dr. Ure justly remarks, its servile inhabitants place their fortune in treasure, and love to hoard up that precious metal. It is evident, however, from the quantities existing in the East, that it must be extracted in considerable amount from various sources. It is found in the rivers of Syria and other parts of Asia Minor. The Pactolus, a small river of Lydia, is said to have rolled over golden sands, which were supposed to have constituted the origin of the proverbial wealth of Croesus. Numerous gold mines are known to exist on the Cailas mountains in the Oundes, a province of Little Thibet, where the gold is found in quartz veins, which traverse a very crumbling reddish granite. It is met with also in the peninsula of Hindostan, and in the islands of the Eastern Archipelago; and it cannot be doubted that considerable quantities are found in Japan and China.

Africa.—It is now the general opinion that the land of Ophir, so frequently mentioned in the Old Testa-

ment, was in Africa, which still presents in one part a territory known as the Gold Coast, implying by its very name the existence of the precious metal in this quarter of the globe. The territory so called, from which large quantities of this metal were formerly exported, lies on the west coast; but the land of Ophir is supposed to have been on the East coast, opposite Madagascar, where a certain amount of gold is still collected. But the principal supplies of this metal are now found at Kordofan, between Darfur and Abyssinia, known to the ancients as Ethiopia, and the western region extending south from the river Senegal to the Cape of Palms, near the Gold Coast. In these districts the gold occurs in spangles, chiefly near the surface of the earth, in the beds of rivers and rivulets, and always in a ferruginous earth. The gold which is brought from Africa is always in dust, showing that the metal is obtained by washing the alluvial soils. Although this division of the globe is supposed to have been the source of the greater portion of the gold possessed by the ancients, yet the whole supply now obtained from that continent is not estimated at more than five thousand pounds annually.

South America.—Brazil furnishes the greatest part of the gold which is brought into the market from South America, and was once the principal gold region of the new world; but its mines and auriferous sands seem to be nearly exhausted. The greatest quantity of gold was obtained from Brazil between the years 1753 and 1763, and since that time it has always been on the decrease. It was in the valley of the Mandi, a branch of the Rio Dolce, at Catapreta, that the auriferous ferruginous sands were first discovered in 1682; but they have since been found widely extended at the foot of the great mountain chain which runs parallel with the coast from the fifth to the thirtieth degree of south latitude. The precious metal is found in nearly all the rivers which form the upper branches of the Francisco, Araguay, Tocantius, and Guaporè; but the largest proportion is found in the affluents of the Francisco. The rock in these localities consists of primitive granite, inclining to gneiss; and the soil, which is of a red, ferruginous character, often extends to a considerable depth. It is from this soil that the gold is extracted by washing. Indeed the veins containing the metal are seldom worked. The most numerous washings are established near Villa Rica, in the environs of Cocães, where the gold occurs either mingled with the sands of the river, or in the alluvial valley deposits. The pepitas occur in various forms, often adhering to micaceous specular iron. In the province of Minas Gerães, the gold is extracted both by the excavation of veins and by the washing of alluvial deposits.

This metal is likewise found in many other parts of South America, on both sides of the great chain of mountains which runs parallel with the Western coast. Peru is richer in silver than in gold ores, but in some parts gold is mined in veins of greasy quartz, variegated with red ferruginous spots, which traverse primitive rocks. All the gold furnished by Columbia, comprehending New Grenada and Venezuela, is the product of washings established in alluvial grounds. But Brazil is the principal gold region of the South American continent.

North America.—More gold is now produced in the vast continent of North America than in any other part of the world. In this respect it has now taken the place which formerly belonged to South America, while the latter has sunk into comparative unproductiveness, less perhaps from the absolute exhaustion of the auriferous soils, than from the want of the capital and enterprise to work them successfully. North America was a gold-producing continent long before the discovery of the Californian treasures; but for many years, the only source of this precious metal in that quarter of the globe was the argentiferous veins of Mexico, from which it was extracted along with the silver, as in the Peru mines of South America. At a later period, however, an extensive gold region was discovered in the United States, extending along the Eastern slope of the Appalachian mountains, from the river Rappahannock in Virginia Southwards to the river Coosa, an affluent to the Alabama, which flows into the Gulf of Mexico. The metal is found in less quantity Northward along the same mountainous range to the State of Maine, and even extending into Canada, where a search for profitable workings has lately been prosecuted with some vigor. The existence of spangles and pepitas of gold, in several rivers of the East of Canada, has been fully established; and at the Great Exhibition honorable mention was made of the Chaudière Mining Company, who exhibited pepitas of native gold, collected in the washing of those streams. But the States of Virginia, North and South Carolina, and Georgia, afford the most productive deposits. In these, as in those of Brazil and Columbia, the auriferous ores are chiefly pyritical; much of the gold is extracted by amalgamation, after stamping under water.

But all preceding gold discoveries in America, or in any other part of the world, were eclipsed by those that have been made within the last few years in California and Australia. These recent discoveries have produced quite a revolution in the annual production of gold, the effects of which, though already powerfully felt in the new impulse given to emigration and commerce, are only beginning to be developed, and must produce the most important results in the future history of the world. This may be inferred from the fact, that the gatherings of the precious metal, reckoning the average produce of all parts of the new and old world for a series of years previous to 1847, did not amount to the annual value of five millions sterling, whereas the amount now exceeds thirty millions per annum.

The first of these recent discoveries was made in 1847, when California, a hitherto-neglected and little-known region, lying at the most remote South-western limit of North America, rose into sudden importance, as the El Dorado of the new world. The gold region, properly so called, occupies the Northern part of California, commencing near the mouth of the Sacramento river, in lat. 39° north, and long. 122½° west, to the north-east of the bay and town of San Francisco, from which it extends south and north. At this point two rivers unite and discharge themselves into the sea—the Sacramento flowing from the North, along a valley formed by mountain ranges, and the San Joaquin, flowing from

the South, along a similar valley, enclosed on one side by the Rocky Mountains, and on the other by the mountainous ridge which protects the Western coast. It was on the property of an intelligent Swiss emigrant, Captain Suter, who had become a wealthy settler on the banks of the Sacramento, that the first traces of gold were discovered in September, 1847. This happened in the course of the erection of saw-mills on the estate, when Mr. Marshall, the contractor for the building of these, observed glittering particles in the sand of the mill-race, which were ascertained to be gold; and on making further researches, it was found that the precious metal was very extensively diffused in the bed of the stream. The discovery soon became known to the work-people, by whom the intelligence was conveyed to San Francisco, and in no long time, the whole population of the little town, and the scattered and scanty settlers in the neighborhood, abandoned their dwellings and occupations to engage in the exciting search. The supply exceeded the most exaggerated accounts that had been given; new and richer localities were discovered; the gold was found in the beds of various streams flowing into the Sacramento; in the mud of the river itself; in the channels of old water-courses, and along the sides of the hills. The intelligence rapidly spread to the neighboring countries—to Mexico, to South America, to the United States, and thence to Europe. People began to flock from all quarters to the once neglected, but now coveted region; it became, in a few short months, the scene of a considerable population, instead of a few scattered tribes of Indians; miners or diggers in parties spread themselves over the face of the country; and San Francisco, from a mere village, grew up into a place of wealth, importance, and stirring activity. It was at first very generally thought that the supply would soon fail, but this anticipation has proved to be unfounded; and while, on the one hand, the amount of the precious metal disseminated in the rocks and soil appears to be almost inexhaustible—on the other hand, the constant increase in the number of miners, combined with the improved apparatus and methods of working, seems to have hitherto resulted in a steadily increasing annual produce, until within the last few years, when it seems to have been nearly stationary.

Professor BLAKE, who minutely examined the auriferous regions of California, states that, with the exception of the diluvial strata, the whole geological formation of the Sierra range, through which flow the principal rivers, consists of igneous and metamorphic rocks. The former are mostly porphyritic in the lower hills, whilst higher up trachytic rocks are more frequently met with. The metamorphic rocks consist of micaceous schists, slates both talcose and micaceous, metamorphic sandstones and limestones, with occasional beds of conglomerate. In that part of the country which he examined, the extent of the diluvial deposits was commensurate, or nearly so, with that of the gold-bearing region. They are found in a belt of land from thirty to sixty miles broad, and running parallel with the axis of the range. These diluvial deposits are met with towards the lower hills of the Sierra, extending frequently some miles into the plain. The elements

of which they are composed differ considerably in various localities, although there are many points of resemblance through the whole series. In the lower valleys and flats, between the ranges of the lower hills, they appear to consist of beds of gravel, containing occasional boulders of quartz and the harder rocks. On the elevated flats, higher up in the mountains, the surface of these deposits is generally covered by a reddish loam, mixed with small gravel; whilst, reposing on the bed rock, and a few inches above it, is found a stratum containing large boulders and gravel, the boulders being principally quartz. At other points, the whole series consists of conglomerates and soft friable sandstone. Where the deposits are found extending over a large surface on the elevated flats, gold is always met with, generally diffused through the gravel immediately above the rock on which they rest, which yields from fifteen to forty cents to the hundred pounds of earth. There are parts where acres of these deposits have been turned up, in which the gravel never contains less than fifteen cents to the hundred pounds, and generally more. In the valleys in the lower hills, and even on the plains to the west of them, where they are extended over vast tracts of country, these deposits are still auriferous, the gold being very generally diffused, and found in greater quantities the deeper they are worked; but sometimes they will not pay for working, owing to the distance from water. In one place, where water could be readily obtained, a portion of these deposits, situated to the west of the lower hills, was found to yield from five to thirty cents to one hundred pounds of earth, through an extent of one hundred and fifty acres, the soil being found richer the deeper it was worked.

At a spot which was appropriately named Mount Ophir, the auriferous soil was described as soft clay and slate, saturated with gold in small particles and large lumps. This treasure was found from ten to thirty feet below the surface, and seven Mexicans, who made the discovery, and kept their secret eight days, made in that short time two hundred and seventeen thousand dollars. Other searchers, from a shaft twenty feet deep, obtained the soft clayey slate in buckets, and found from eight to twelve dollars' worth of gold in each bucket. In many cases considerable nuggets are met with, but no accounts speak of very large masses of gold having been found in California. The total produce from this region, down to the end of 1855, was estimated at sixty-four million pounds sterling; and, latterly, it has averaged about fourteen million pounds per annum.

Australia.—The world-wide excitement created by the gold discoveries in California had scarcely subsided, when another auriferous region was developed in the British dominions at the antipodes, which promises to prove not less productive. The Californian treasures were discovered in September, 1847; and in the spring of 1851 the long-concealed wealth of Eastern Australia was first announced to the world. It is remarkable that this second discovery was not made sooner; for so early as in 1841, the Rev. W. B. CLARKE, in examining the geological structure of the Blue Mountains of Eastern Australia, was attracted by the plutonic and

metamorphic character of the axis of the range, and by the presence of gold in the quartzites, and in the detrital accumulations derived from the axial formations. This gentleman, a native geologist, had found evidence of the existence of gold within sixty and eighty miles of Sydney, and had affirmed his belief that the Blue Mountains would at some time prove to be auriferous. Again, in 1845, Sir RODERICK MURCHISON expressed the same conviction, when he compared the Eastern chain of Australian mountains with the Ural; and in 1846 he even recommended the unemployed Cornish tin miners to emigrate to New South Wales, and dig for gold in the debris and drift of the Australian cordilleras. His writings and remarks on this subject were not entirely without effect, for in 1847 he received letters from speculators in Sydney and Adelaide, accompanied with specimens of gold, which they had sought and obtained, in consequence of his suggestions; and shortly afterwards he even wrote to Earl GREY, informing him that his anticipations were about to be realized in a manner which might operate a great change in the colony.

The discovery was at length made through the instrumentality of a gentleman named HARGRAVES, who had recently returned from California, and had then occupied himself for two months in exploring a considerable extent of country in Australia. On the third of April, 1851, this gentleman addressed a letter to the Colonial Secretary, stating that he had prosecuted his speculation to a successful issue, and offering, for the sum of five hundred pounds, to point out to the officers of Government the localities in which he had discovered gold. To this proposal the Secretary replied that he was not authorized to make a blind bargain, but that if Mr. HARGRAVES thought proper to trust to the liberality of the Government, he might rely on being rewarded in proportion to the value of the discovery. Accordingly, on the thirtieth April, Mr. HARGRAVES addressed another letter to the Colonial Secretary, expressing his willingness to leave the remuneration of his discovery to the liberal consideration of the Government, and naming the localities from which he had obtained specimens of the precious metal. These were at Summer Hill Creek, and other places near Bathurst, which is situated about a hundred and fifty miles west of Sydney, New South Wales.

Scarcely had this communication been made to Government, when the discovery became generally known, through some persons who had been employed under the directions of Mr. HARGRAVES. The fact was divulged that on the eighth of May these persons had obtained several ounces of gold at Summer Hill Creek; and on the thirteenth of the same month great excitement was created by the report that a solid piece, weighing thirteen ounces, had been found. This, on inquiry, proved to be correct, and hundreds of persons immediately left their accustomed avocations, and started for the *diggings*, as they were now called. The excitement rapidly extended, and on the nineteenth of May four hundred persons were congregated at Summer Hill Creek; on the twenty-ninth, one thousand; and on the fifth June their numbers had increased to fifteen hundred.

The Government now lost no time in adopting the necessary measures for maintaining order. A proclamation was issued, dated twenty-second May, 1851, declaring that, from and after the first of June, all persons digging for gold without a license would be proceeded against; and authorising the crown commissioners to grant such licenses for a fee of thirty shillings per month. A force was appointed for the purpose of collecting the fees, and strong detachments of police were stationed along the principal roads leading to the gold fields. At the same time, Mr. HARGRAVES, and the Government geological surveyor, Mr. STUTCHBURY, with whom Mr. CLARKE was afterwards associated, were ordered to make an immediate survey of the various localities in which it appeared probable that gold would be found.

But the spirit of enterprise was now awakened in the diggers themselves, and soon conducted them to new and richer deposits of the precious metal. From Summer Hill Creek, to which the name of Ophir had been given, a great emigration took place to the Turon River—another of the localities first pointed out by Mr. HARGRAVES, and lying a little to the Northward of Summer Hill; and in the month of December the number of diggers on the Turon amounted to six thousand. Subsequently, gold was discovered at various other places in Bathurst, as well as in the adjoining counties of Wellington, Roxburgh, Georgiana, and Ashburnham. Latterly it was found so far South as St. Vincent, and ultimately over the entire mountainous range of New South Wales, extending from 27° to 37° of south latitude; but more abundantly in the Southern portion of the province.

But the progress of discovery did not confine itself to New South Wales. It still advanced to the South; and in a despatch, dated twenty-fifth August, 1851, Lieutenant-Governor LATROBE communicated to Earl GREY, that large deposits had been found in the colony of Victoria. The three localities first named were: Clune's Diggings, about forty miles from Melbourne, where the gold was found in an alluvial deposit, consisting chiefly of quartz gravel; at Buninyong, near Ballarat, about eighty miles from Melbourne or fifty from Geelong, where the gold was sometimes imbedded in compact quartz; and Deep Creek, only nineteen miles from Melbourne, where the precious metal was found to exist in connection with slate rock. It was afterwards discovered almost in the neighborhood of Geelong, and likewise at a place called Mount Disappointment, about thirty miles to the North-east of Melbourne; and, finally, the people of that town began to break up the streets, which had been macadamized with quartz pebbles obtained from the gold districts.

The excitement created in the colony of Victoria by these discoveries surpassed even that which had taken place at Sydney. The whole neighboring population were moving towards the gold regions; Melbourne and Geelong were almost emptied of their inhabitants; and it was found impossible to retain the services of the Government employes, without an addition to their salaries of—first, twenty-five, and, subsequently, fifty per cent. Even the superior class of farmers and tradesmen were drawn into the vortex, partly from sharing

in the general mania, and partly because, when deprived of their laborers and assistants, they had no alternative but the diggings. For some time Ballarat was the great source of attraction, and the stories told of its productiveness were almost incredible. Eight feet square of that auriferous soil was deemed a fortune. One man had found fifteen hundred pounds' worth of gold in one week—another man a thousand. A party of three men had met with twenty pounds' weight in one day!

But even Ballarat was shortly surpassed by a fresh gold-field discovered in the Mount Alexander range, still further to the north, about ninety miles from Melbourne. This was found to exceed in richness all the diggings previously discovered. So great were the attractions of this new field, that the number of diggers at Ballarat, which had risen to six thousand, was quickly reduced to one thousand six hundred, while the number at Mount Alexander rose to twenty thousand. This was the climax of the excitement created by the gold discoveries. The whole structure of Australian society became for a period completely disorganized. Subsequently the precious metal was discovered at various other localities, and the supply was so far increased that gold arrived at the seaports at the rate of two tons per week. The excitement has now subsided; and no new localities have been reported, yielding the same fabulous treasures as Ballarat and Mount Alexander, when first discovered; but various new sources have been opened up, and a map of the country, exhibiting the gold regions, seems to indicate the precious metal as disseminated in greater or less abundance over the whole of the mountainous range which extends through New South Wales and Victoria. The field of operations, therefore, continues to extend; improved machinery is brought into action; and the consequence is, that, while less excitement exists, there is more of steady productive labor, and the aggregate supply of the precious metal has continued to increase yearly till the present time, when it seems to have attained nearly its maximum, at thirteen millions per annum. It is expected, however, that when the labors of the large numbers now employed in deep sinking and in quartz mining are brought to a profitable consummation, the yield, if not greatly increased, will at least be permanently sustained. Further details on this subject, and the produce of the principal mines and auriferous regions throughout the world, will be given at the close of the present article, under the head of Statistics.

ORIGIN AND POSITION OF THE GOLD DEPOSITS—The matrix of the gold in Australia, as in other auriferous regions, is quartz. The general character of the soil may be inferred from the description given of the Turon and Summer Hill Creek districts, where the gold was first found, and where, according to Mr. STUTCHBURY, the Government geologist, the whole area may be considered as schistose, principally clay-slate, accompanied by nearly all the other varieties of slate rocks, and also by a large amount of quartzites in veins or lodes, parallel to the stroke of the schist. In this district, the trend of all the waterways, or *creeks*, in which the gold is chiefly found, is into the Macquarrie river. The

quartz is amorphous, very rarely crystallized; and in the neighborhood of the gold-yielding localities, it is accompanied by titaniferous iron, both crystallized and in loose grains. Many instances occur in which the quartz remains attached, and interlaced by the gold, as also the iron. It is a fact worth recording, that no gold has been found in Australia, without the iron sand—incorrectly termed *emery*—accompanying it.

Gold in small quantities has been found on the summits and upon the flanks of the mountain ranges; but, with few exceptions, it bears evidence of abrasion; and the larger produce in every instance has been found in the lower levels. Assuming that the auriferous deposits originated in the quartz rock, says Mr. STUTCHBURY, there is no difficulty in accounting for its presence most abundantly in the various gullies and creeks so numerous in this remarkably broken country. The schistose rocks, so readily acted upon by the atmosphere, constantly disintegrating and exposing the quartzose dykes, leave them unsupported; and gravitating downwards, the largest blocks are crushed and crumbled in their onward course, letting loose the tenacious gold in large or small portions, which, in obedience to their gravity, and the force of the impelling torrents, roll on until they are arrested for a time in hollows, or the cleavage fissures of the slaty rocks, or quietly deposited in the sand and mud, as the case may be, by the cessation of the flood, until they are again removed by the repetition of similar causes; or they may remain for ages undisturbed, by the torrents taking another course, of which there are so many instances, leaving ancient bars of shingle debris now covered by accumulated soil. It therefore follows that gold, even if it be of the earliest geological origin, may and will be accumulating in the lower valleys, as long as mountains waste and valleys exist for its reception.

It has been asserted, however, by some writers, that the gold, instead of being torn out by the waters from the veins and primitive rocks which they traverse, actually belongs to the grounds washed by the waters as they glide along. In proof of this, it has been urged that gold is almost always found among the sands of rivers only in a very circumscribed space, and that on ascending these rivers, their sands cease to afford gold, whereas, did this metal come from the rocks above, it should be found more abundantly near the source of the rivers. Thus, the late Dr. URE remarks, that the Orco contains no gold except from Pont to its junction with the Po. In like manner, the Ticino affords gold only below the Lago Maggiore, and consequently far from the primitive mountains, after traversing a lake where its course is necessarily slackened, and into which whatsoever it carried down from the mountains must have been deposited. The Rhine gives more gold near Strasburg, than near Basle, though the latter be much closer to the mountains; and the sands of the Danube contain no gold, so long as the river runs in a mountainous region—that is, from the frontiers of the Bishoprick of Passau to Efferding—but they become auriferous in the plains below. The same thing is stated of the Ems, and other rivers; and it must be admitted that the opinion, to which it naturally leads,

rests upon very strong grounds, and is supported by some of the highest authorities.

Though gold is frequently found at the surface, mixed with the sands of rivers, yet the auriferous stratum is often buried at considerable depths, and hence the necessity of opening *pits* or *diggings*. Figs. 204 and 205 will afford some idea of the Australian gold-field strata. The latter represents what the diggers call a surface gullet, the gold being met with at about sixteen feet from the surface; the former is a



Fig. 204.



Fig. 205.

section of a deep gullet, in which the auriferous ore is at a depth of thirty-six feet. The corresponding letters, in both sections, indicate similar strata; *a*, black loam and quartz; *b*, white loam, clay, and sand; *c*, brown clay; *d*, gold layer; *e*, yellowish-brown rock; *f*, quartz in a concrete mass; *g*, stratum of sand; *h*, common clay. The auriferous ore is generally of a light color, or largely mixed with quartz pebbles, very tenacious and difficult to wash. It lies upon a yellowish brown rock, of a rotten texture, known as fixed slate, whilst higher up, above the gold, the strata present igneous features.

Probable abundance of Gold at great depths.—The probability that gold exists in almost unlimited amount at greater depths than have been yet explored for this metal, is thus argued by Mr. W. BRIDGES ADAMS: Quartz rock is the matrix of gold, and quartz rock is commonly a vein of greater or less thickness intersecting the beds of granite. In this quartz the metallic gold is distributed, in particles of more or less fineness, and sometimes it is found in lumps. If the granite be supposed to have been once in a state of fusion, and cracked in cooling, forcing up into the fissures the liquid quartz containing the gold, it seems more than probable that the greater part of the molten gold would settle to the bottom of the fluid mass, as the metal precipitates in an iron furnace, beneath the slag. The fragments that are found in rivers and alluvial ground have probably been thrown out by subsequent volcanic action. The spangle-gold, the nuggets, the gold-dust, and other varieties, seem to confirm this; and probably, in depths of alluvion greater than have yet been penetrated, large golden fragments will be discovered, just as the hugest pieces of rock are found undermost in the beds of mountain torrents. If this theory be correct, it is quite within possibility that the gold-hunters, who have as yet explored but a small portion of the earth's surface, may light upon larger deposits—may yet penetrate to some mass larger than the famed native iron of Santiago del Estero, or a quartz vein gradually changing into the

pure metal. The lighter fragments washed to the edges by the stream have alone been gathered; they are but indications of the larger masses that lie in deposit below; and it may be predicted that wherever gold has been superficially gathered at any period, it will be found in larger masses at some greater depth.

If there be any truth in this ingenious conjecture, it will soon be brought to the test of experiment by the operations now in progress in Australia, with a view to deep sinking and quartz mining on a very extensive scale.

METHOD OF EXAMINING AURIFEROUS DEPOSITS.—

As a general rule, the rocks in the district to be examined for gold should be either granitic, porphyritic, or quartzose, although it is also found in other formations, and particularly in clay-slate. The auriferous quartz is often stained of a rusty brown color, from the presence of peroxide of iron, and in many instances presents a cellular or honeycombed appearance. The points to be most carefully examined are the sands of the rivers and streams, or old water-courses, as well as the particles of disintegrated rock which often accumulate in the eddies of ravines formed on the sides of hills by the action of water during great floods. The sections of rock exposed by this action must also be examined with a view to the discovery of veins of auriferous quartz, from which specimens are broken off and afterwards carefully assayed.

The method of conducting a systematic assay of gold ores and alloys will be fully explained afterwards. It is a somewhat tedious and difficult process, requiring considerable experience and a regular assortment of apparatus. But even in the absence of these, a tolerably correct estimate of the amount of gold present may be readily arrived at by the following simple method.

The fragment of rock, supposing the ore to be quartz, is first pounded very fine and sifted, a portion of the sand or powder thus obtained is washed in a shallow pan, and, as the gold sinks, the lighter portions of the substance are allowed to float off. The greater part of the gold is thus left in the angles of the pan; and by adding more of the powder, and repeating the same process, a further portion is obtained. When the bulk of powder, with which the gold is mixed, is thus reduced to a manageable quantity, mercury is added to the mass, and forms with the gold an amalgam, which is afterwards heated in an iron retort to expel the mercury. In this way the proportion of gold contained in a specimen of rock may be ascertained with considerable exactness. The sands brought down by rivers are examined in much the same manner, but do not require the previous pounding; and a fair estimate of their value may be generally formed without the amalgamating process. Sometimes, indeed, the gold may be present in considerable quantity, although in a state of division so minute as not to be readily perceived by the unassisted eye, and, therefore, in examining the earthy residuum, a small magnifying lens will be found of great use.

It is generally considered that the sand of any river

is worth working for the gold it contains, provided it will yield twenty-four grains to the hundredweight; but the sands of the African rivers often yield sixty grains in not more than five pounds weight, which is in the proportion of more than fifty times as much, while the Australian rivers have been known to yield considerably more.

SUBSTANCES OFTEN MISTAKEN FOR GOLD.—

Though gold, in its separate and pure state, is readily distinguishable from other metals and minerals, by its color, softness, high specific gravity, and insolubility in the simple acids, yet in the mixed state in which it is generally found it requires an amount of chemical skill to apply these tests, and hence, where glittering particles of other minerals appear, they are often mistaken for gold, even by persons who are not entirely ignorant of its characteristics. The substances which most generally lead to this mistake are iron pyrites, copper pyrites, and yellow mica.

Common iron pyrites, or *bisulphide of iron*, which is more frequently mistaken for gold than any other substance, occurs in small cubical crystals, in veins disseminated in the various slate rocks, and in the coal measures. It is of different shades of brass-yellow, and often in fact contains minute traces of gold, though seldom a sufficient amount of that metal to render its extraction profitable. It may be readily distinguished from gold by the application of the magnet, as well as by the following characters: first, instead of flattening like gold under the hammer, it is extremely brittle, and, therefore, readily broken; second, its weight or specific gravity is only about one-fourth that of gold; and lastly, when heated with nitric acid it is dissolved with evolution of copious red fumes, whilst gold, when so treated, remains unaffected. It was only recently the Editor was consulted by a gentleman who imagined he had discovered a gold mine in Ireland. The sample brought turned out to be a fine specimen of sulphide of iron embedded in quartz.

Copper pyrites, or *yellow copper ore*, the second mineral which is frequently mistaken for gold, is a ferrosulphide of copper, and may be considered as a compound of two equivalents of sulphide of iron, and one equivalent of sulphide of copper. This is the ore from which the largest proportion of the copper of commerce is derived. It occurs in a variety of forms, its primitive crystal being the regular tetrahedron. It is formed in lodes or veins, which usually occur either in granite, grauwacké, or clay-slate, and has a strong metallic lustre, and deep brass-yellow color. It may readily be distinguished from gold by the circumstance, that when heated on a piece of charcoal before the blow-pipe it loses this yellow color, and fuses into a dull black globule, which, from the presence of the iron, is magnetic. If mixed with carbonate of soda and a little borax, it yields, when similarly treated, in skilful hands, a button of metallic copper. But an easier method to determine the presence of copper is to pulverize the ore in an iron mortar, or with a heavy hammer, dissolving the powder thus obtained in nitric acid, and evaporating the solution nearly to dryness; water is then added, and afterwards ammonia in excess, when, if copper be present, the liquor assumes a rich pur-

plish color, an unmistakeable sign of the presence of copper.

Another method for determining the presence both of iron and copper, is to take some of the scoria left after submitting it to the blowpipe, and, putting this in a test-glass, to pour over it a few drops of hydrochloric acid, when an effervescing solution will be obtained. A little of this liquid is then transferred to another glass—the one to be treated for iron, the other for copper. Into one of the glasses introduce a few drops of ferro-cyanide of potassium, and liquid ammonia into the other. If iron is present, the liquid in the glass to which the ferro-cyanide has been added will become blue, the iron combining with the ferro-cyanogen, and producing Prussian blue. If copper is present in the same glass, but no iron, the liquid will become of a reddish-brown tint, ferro-cyanide of copper being formed. If iron and copper are present together, the two metallic precipitates will be the result, and a purple tint arises from the mixing of the red and blue colors. The liquid in the glass to which ammonia was added will be changed to a brownish tint if iron is present, and to a fine blue if copper is there.

Mica, the third substance often mistaken for gold, is one of the constituents of gneiss granite and mica slate, and gives to the former its lamellar structure. In 1853 great excitement was produced at the Cape of Good Hope, in consequence of the discovery, near Simon's Bay, of a substance said to contain a large proportion of gold. A quantity of this suspected mineral was sent home for analysis, and was found to possess a glistening, yellow, semi-metallic lustre; but when submitted to the searching powers of the microscope, its metallic brilliancy disappeared, especially when viewed by transmitted light. It had then a darkish-grey color, being in thin semi-transparent plates. It was not acted upon by nitric or nitro-hydrochloric acid; and hence, doubtless, arose the error in taking it to be gold. In reality, it was nothing but mica, highly colored with the oxide of iron, and yielding, on analysis, the following constituents:—

	Centesimally.
Silica,	46
Alumina,	23
Potassa,	14
Oxide of iron,	16
Manganese,	1
	100

The specific gravity of mica never exceeds 3.00; and this circumstance, together with its foliated structure, is quite sufficient to distinguish it from gold, which it somewhat resembles in color; but even in this latter particular, the microscope will dispel the illusion.

CHARACTERS OF NATIVE GOLD.—Gold, as already stated, almost always occurs in the metallic state, generally in small grains or scales known as *gold dust*, sometimes in particles so minute as to be invisible, but occasionally in pieces of considerable weight, termed *nuggets*. It appears doubtful, indeed, whether, when this metal occurs in pyrites, it exists in every instance in minute metallic particles, or whether, in some cases at least, it may not be present in combination with sulphur. The auriferous pyrites, as DUMAS remarks, con-

tain the gold disseminated through their mass in such small quantities, that it is almost always impossible to ascertain, even with the aid of the microscope, in what state the precious metal exists. As a preliminary roasting of this auriferous ore is generally useful, with a view to the subsequent amalgamation, a doubt may be entertained whether it is really present in the metallic state, though this has been generally assumed hitherto. But DUMAS thinks that the powerful electro-negative tendency of sulphide of gold affords a strong presumption in favor of the hypothesis, that this metal may exist partly, or even entirely, under the form of a double sulphide, in iron and copper pyrites, *et cetera*. BROGNIART observes, that it is chiefly in its association with these sulphides, as also with galena or sulphide of lead, blende or sulphide of zinc, and mispickel or arsenical pyrites—a sulphide of arsenic and iron—that the gold becomes invisible to the eye, a circumstance which is justly regarded as strongly confirming the opinion expressed by DUMAS. The other minerals with which it is found associated are grey cobalt, lithoidal manganese, native tellurium, malachite, sulphide of silver, red silver, and sulphide of antimony.

When the gold is found in the form of nuggets, these generally communicate the impression of their having been melted; and in many newspaper accounts, and

Fig. 206.



letters received from the diggings, the gold is described as having been evidently in a state of fusion, and as resembling drops of melted metal poured into sand, the indentations being visible even upon the smallest particles of the gold when microscopically examined. It is certain that such indentations may be observed in most

specimens, as indicated in Fig. 206, which exhibits a microscopic view of a fragment of Australian gold magnified seven hundred times. Mr. J. B. JUKES, however, who may be regarded as a competent authority, conceives that this is probably a mistake, and that the idea may have originated from the gold having been deposited in small holes, crevices, and interstices of the quartz rock, and subsequently rolled, so that it assumes such forms as melted lead is seen to do. It does, certainly, appear remarkable that the particles of gold should retain indentations received in a state of fusion, after being tossed about, probably for a long period, among water and gravel.

Fig. 206 has been given as the greatly magnified representation of a very small grain. Fig. 207, on the contrary, is a much reduced delineation of a lump of almost pure gold, weighing 27 lbs. 6 oz. 15 dwts, which was found in the diggings, at Forest Creek, Mount Alexander, in the Colony of Victoria. Among other pieces brought home with it in the same vessel, were several nuggets weighing upwards of a pound each,

and one of 1 lb. 8 oz. 6 dwts. These smaller lumps, however, contained quartz, whilst the larger one appeared a massive lump of nearly pure gold, of a very fine color. It measured eleven inches in

Fig. 207.



length by five in breadth, at the widest part. This was supposed to be the largest nugget which had been found in Australia up to the time of its discovery, but one or two others considerably larger have been since obtained.

Gold is also occasionally, though rarely, found in a crystallized state; and when met with, the crystals should be carefully preserved as cabinet specimens, for which purpose their value is much greater than that which they are intrinsically worth for the gold they contain. The most common forms are the cube and octahedron, with their various modifications. The faces are generally dull, and in most instances the edges are slightly rounded. Some years ago, several interesting specimens of crystallized gold, from California, were described in *Silliman's American Journal*, by Mr. FRANCIS ALGER of Boston. The collections in which the specimens were found were brought from California by Mr. G. E. TYLER of Boston, and Mr. H. B. PLATT of New York. The crystals were distinctly octahedral, simple and modified, the surfaces being but slightly disfigured by attrition, or the effects of transported action—a very unusual circumstance, as gold is generally found in comparatively minute grains, at a distance from the rocky matrix in which it is supposed by some to have been primarily embedded. Mr. ALGER states in his paper, which was read before the Boston Society of Natural History, that he had never before seen what was unquestionably a genuine crystal from California. He adds that an irregular crystalline plane could only occasionally be traced out in former specimens; but among those exhibited were examples of crystallization as perfect, among the small ones especially, as are to be seen in magnetic iron ore or in spinelle.

Of the larger specimens in these collections, the most striking examples were three octahedrons of the sizes exhibited in Figs. 208, 209, 210. Each of these crystals was found in an isolated state. The smallest one—Fig. 208—was the most perfect, and was entirely free from any adhering portion of the matrix. This unusually perfect crystal exhibits, as partly shown in the Figure, four pretty regular faces in the lower half, and three of its six solid angles are perfectly formed to a point. Two of its faces are sunk or depressed; and in one of them, the cavity thus formed, is very deep and regular, like an interior triangle; the depression extend-

ing not quite to the edges, but so as to leave all round a narrow ridge or border, the interior sides of which are parallel with the edges of the crystal. Mr. ALGER in-

Fig. 208.



Fig. 209.*



Fig. 210.



ferred that this depression, which is shown by a darker shade in the wood-cut, had been formed when the crystal was in a liquid state, and that, soon after the outside had congealed or solidified, the inner portion, or a part of it, had run out, leaving the surrounding consolidated edge in a perfect form. He remarks that he has seen something similar to this formed among artificial crystals, as, for instance, metallic lead—which takes the form of an octahedron—and lead ore partially desulphurized, when the metal was allowed to flow off slowly, just as the outer crust had formed over the surface of the crystals. Indeed, this parallel case is of not unfrequent occurrence in the crystallization of the ductile metals.

In the largest—Fig. 209—of the three crystals of which the preceding sketches are given, it will be observed that only one-half of the octahedron is formed, its base blending with the rough gold, or showing only the commencement of the planes of the upper pyramid. Three of the planes are quite smooth, except along their edges, which are permanently marked by the same projecting border or edge described on the smaller crystal. The depression, however, is not so great as in the latter. Mr. ALGER remarked that this peculiarity was confined to the unmodified crystals.

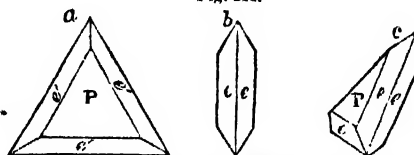
In some there was a double series of these ridges, the inner one appearing to exhibit the commencement of another crystalline face within the cavity of the larger one. This phenomenon was strikingly shown in a crystal represented of the natural size in Fig. 210.

The two larger crystals—Figs. 209 and 210—were obtained from the collection of Mr. PLATT, who resided a couple of years at San Francisco, and being in a situation which brought him into constant intercourse with persons returning from the mines, purchased, at no small expense, the most interesting specimens he could find. His collection was described by Mr. ALGER as of singular beauty and value, comprising a great variety of ramified, arborescent, dendritic, and other imitative forms, all of them, sometimes, fantastically joined together in the same specimen. In obtaining his valuable collection, he had examined gold to the amount of more than four millions of dollars. The remarkable size of the two larger crystals thus described, and the fact that some of the others contained portions of oxide of iron, induced a suspicion that the greater part of them were pseudomorphs of sulphide of iron; but Mr. ALGER believed that they were formed

under the ordinary circumstances of crystallization, either in an open space, or while surrounded by a matrix, in such a fluid state as to allow them full freedom to take their natural form. His reasoning on the subject, if not perfectly conclusive, leads to a strong presumption in favor of the octahedron as the primary form of gold; and if this were more generally known, much disappointment and trouble might be saved in cases where sulphide of iron and other crystalline metallic forms are mistaken for the precious ore.

In Mr. TYLER's collection, Mr. ALGER found several rare modifications, some of them resembling those which come in their most perfect forms from Brazil. Fig. 211 exhibits in three positions, *a*, *b*, *c*, a compound form produced by the union of two opposite segments of an emarginated octahedron. Fig. 212 is a modifi-

Fig. 211.



cation of the same form, though apparently consisting of irregular six-sided tables, with truncated edges. Some of the unmodified macles, as shown in different positions, in Fig. 211, were stated by Mr. ALGER to be very distinctly formed, the edges between *ee*, uniting the two segments of the octahedron, being well

Fig. 212.



Fig. 213.



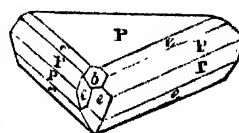
Fig. 214.



defined. This is very strikingly shown in Fig. 213, in which the crystals are exhibited as magnified to twice their natural size. Fig. 214 shows the opposite side of the same specimen, connected with two other crystals, one a very beautiful and smooth-planed octahedron with emarginated edges.

Fig. 215 exhibits a macle of gold which came from Malto-Grosso in Brazil, and is in the collection of the School of Mines, Paris. It is similar to that represented in Fig. 211, from which it only differs in exhibiting more of the planes of the octahedron and dodecahedron. This figure is copied from the volume of crystallographic illustrations accompanying M. DUFRÉNOY's treatise; but besides conforming his lettering to the notation of PHILLIPS, those are made primary planes which are given by DUFRÉNOY only as secondaries of the cube.

Fig. 215.



In all these the octahedral form is manifest, which may therefore be assumed to be the form natural to gold when its particles crystallize in cooling; but as nearly all of these crystals show the effects of abraded action, it is often difficult to distinguish planes confined within such narrow limits, and which are too small or too rough to admit of accurate admeasurement. Indeed the faces of the crystals are in most instances slightly rounded, even in specimens obtained directly from veins, and which, consequently, cannot have been exposed to attrition.

COMPOSITION OF NATIVE GOLD.—Native gold is never quite pure, being almost invariably alloyed with silver, and containing frequently small proportions of copper and iron. In Siberia it is often associated with platinum, and in the Gongo Soco mines in Brazil, an alloy of gold and palladium of a pale yellow color is sometimes found. In Columbia a somewhat similar

mixture is procured, in which the palladium is replaced by another rare metal called rhodium. In Hungary it is met with in combination with tellurium and other elements. The specific gravity of native gold varies from 13.3 to 18.5.

The proportion of silver, the principal ingredient which is found in combination with gold, varies from one to fifty per cent.; and not only differs greatly in specimens of native gold obtained from diverse regions, but even to a certain extent in specimens from the same auriferous district. In general, however, the composition of the gold of the same district is remarkably constant; so much so, that the knowledge of the locality whence it is derived is often sufficient to enable the experienced assayer to guess pretty nearly the quantity of pure gold which the compound contains. The subjoined table presents the composition of native gold from various parts of the world:—

SIBERIA AND URAL.					
Locality	Authority	Gold	Silver	Copper	Iron
Schabrowski,	Rose,	98.96	0.16	0.35	—
Bortuschka,	Rose,	94.41	5.23	0.36	—
Kathemenburg,	Rose,	92.80	7.02	0.06	0.08
Gozuschka,	Rose,	83.85	16.15	—	—
Ural,	Awdejew,	70.86	28.30	0.84	—
AFRICA.					
Anamaboc,	T. H. Henry,	98.06	1.39	0.15	—
Anamaboc,	T. H. Henry,	88.25	11.17	0.10	0.36
AMERICA.					
North of Brazil,	Rivot,	91.0	8.7	0.3	Palladium
Gongo Soco,	T. H. Henry,	83.36	6.44	0.50	3.58
Ojas Anchas,	Boussingault,	84.5	15.5	—	—
Santa Rosa De Oso,	Boussingault,	82.4	15.5	—	—
Marmato,	Boussingault,	73.45	26.48	—	—
Titiribi, Columbia,	Rose,	76.41	23.12	0.03	—
California,	T. H. Henry,	90.12	9.01	0.87	Iron
California,	T. H. Henry,	86.57	12.33	0.29	0.24
Canada,	T. H. Henry,	90.38	9.53	—	—
AUSTRALIA.					
Bathurst,	T. H. Henry,	95.68	3.92	—	0.16
EUROPE.					
Transylvania,	Rose,	60.49	38.74	0.77	—
Wicklow,	Mallet,	92.32	6.17	—	0.78

From this table it will be seen that the gold both of California and Australia contains silver, but that the specimen from the latter was remarkably pure; and such, indeed, is the general character of Australian gold. Neither platinum nor palladium, nor any trace of the metals of that class, is found in the newly discovered gold regions. There is, however, a trace of iron in the Australian specimen, and a small proportion of both copper and iron in those from California.

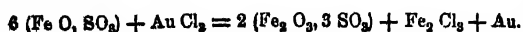
PREPARATION OF PURE GOLD.—Like native gold, that which is used in the currency, as well as in the manufacture of jewellery, is never absolutely pure, being always alloyed with some other metal, such as copper or silver, to give it the requisite hardness. The proportions of the metals which enter into these alloys will be afterwards stated. The methods adopted, also, for obtaining pure gold on the large scale, or, in other words, the metallurgical treatment of gold ores, with a view to the extraction of the precious metal in a state of purity, will be fully explained. In the meantime, it may be desirable, before proceeding further, to show

how a small portion of pure gold may be prepared in the laboratory.

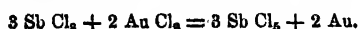
For this purpose, a piece of native gold, a small quantity of gold dust, or a few coins or fragments of old jewellery are dissolved in nitro-hydrochloric acid—the *aqua regia* of the alchemists—consisting of four parts of hydrochloric with one of nitric acid. This will give a solution of terchloride of gold, mixed with chloride of silver, if any of that metal be present. The solution thus obtained is evaporated with an excess of hydrochloric acid for the purpose of destroying the excess of nitric acid. The residue is then treated with hot water, by which it is dissolved, with the exception of the chloride of silver, from which the solution is decanted or separated by filtration.

An excess of protosulphate of iron in solution is then added to the auriferous solution in the proportion of four or five parts of the crystallized protosulphate—green vitriol—to one of gold; and the mixture is put in a warm place, and allowed to stand for several hours. In the reaction which occurs, the chlorine that was combined with the gold unites with a portion of

the iron of the protosulphate, part of which is thereby converted into sesquisulphate, while sesquichloride of iron is at the same time formed, and metallic gold is precipitated. This reaction is represented in the annexed equation :—



To precipitate the gold from an acid solution of its chloride, LEVOL prefers to the protosulphate of iron an acid solution of terchloride of antimony, in which case the following equation exhibits the reaction that takes place :—



In this case, if chloride of silver be present, it is retained by the hydrochloric solution.

The precipitated gold is in the form of a finely-divided powder, which, when suspended in water, is brown by reflected and purple when viewed by transmitted light; but under the burnisher it readily assumes the metallic lustre and characteristic color of malleable gold. It also admits of being aggregated and welded together by percussion; and if heated to whiteness, and in that state struck repeatedly with a heavy hammer, its particles become united into a solid mass, without having been raised to the point of fusion.

To obtain the gold in a perfectly pure state, however, the precipitated powder is boiled with hydrochloric acid of specific gravity 1.1, which is then decanted, and the residue is boiled twice with fresh acid. The gold is *not* washed between these successive treatments with acid, which remove the last traces of iron, and nearly all the chloride of silver.

Lastly, the gold is well washed, dried, and mixed with its own weight of bisulphate of potassa, or a small quantity of borax and nitre, and fused in a Hessian crucible exposed to a very strong heat. By this operation, the last portions of chloride of silver are removed, and a button of perfectly pure gold is obtained.

PROPERTIES OF PURE GOLD.—Pure gold is of a rich reddish-yellow color, and high metallic lustre; in the pulverulent state it is brown and dull, but acquires, as has been stated, the metallic lustre by pressure. The specific gravity of fused gold is 19.2; of hammered gold, from 19.3 to 19.4. In this respect, therefore, it stands only second to platinum, of which the specific gravity is about 21.5. Finely-divided gold, precipitated by sulphate of iron, was found to vary in density from 19.55 to 20.72; and when precipitated by oxalic acid, its density was 19.49. Its equivalent is 197. In a pure state it is softer than silver, and nearly as soft as lead; but its tenacity is so great that it may be drawn out into very fine wire; and such is its malleability that it may be hammered out into leaves only one three hundred and seventy thousandth of an inch in thickness. A single grain may be extended over 56.75 square inches of surface, or drawn out into a wire five hundred feet long. RÉAUMUR, by rolling out a fine gilt silver wire, reduced the coating of gold to the twelve-millionth of an inch in thickness, and the surface appeared to be perfect when viewed under the microscope.

Gold does not combine directly with oxygen, and,

therefore, suffers no change by exposure to air and moisture at any temperature—not even by being kept in a state of fusion in open vessels. It is not attacked by the mineral or any of the simple acids, except selenic, and this by the aid of heat. The alkalis do not affect it, and hence a crucible of gold is a valuable instrument in the analysis of minerals which require fusion with the caustic alkalis. It is not acted on by sulphur, and, consequently, sulphide of hydrogen is not decomposed by it, as in the case of silver. Iodine has only a weak action upon it, but bromine and chlorine attack it easily at ordinary temperatures; and it is dissolved by any substance which liberates chlorine. It is therefore dissolved by hydrochloric acid, if binoxide of manganese, chromic acid, *et cetera*, be added thereto. Its usual solvent is that already stated—a mixture of one part of nitric acid, and four parts of hydrochloric acid. *The proper solvent of gold is nascent chlorine*, which is eliminated by the mutual action of the mixed acids.

Gold is one of the most perfect conductors both of heat and of electricity. It fuses at a bright red or a white heat, the temperature of which has been estimated at 2161° Fahr. It is therefore less fusible than silver or copper, the former fusing at 1873°, and the latter at 1996°. In fusion it exhibits a bluish-green color. It is not sensibly volatile in the strongest heat of a blast furnace; but in the focus of a large convex lens, in the intense heat of the oxyhydrogen jet, or under the influence of a powerful electric discharge, a gold wire is dispersed in vapor; and if, in the latter case, the wire be placed just above the surface of a sheet of paper, the course of the discharge is marked by a broad, dark, purple stain, produced by the finely-divided gold. If, instead of the sheet of white paper, a plate of polished silver be employed, it is traversed by a brightly-gilded line, which is firmly attached to its surface. When a globule of gold is placed between the terminal charcoal points of a powerful voltaic battery, it enters almost immediately into fusion, and gives off abundant metallic fumes.

Gold contracts on cooling, and cannot be advantageously employed for castings, as it shrinks greatly at the moment of solidifying. GRAHAM states that it cannot be obtained in crystals by cooling; but according to other authorities, when large quantities of gold have been fused, and are then allowed to cool slowly, cubes more or less modified on their edges and angles are frequently the result. It has been shown that native gold affords numerous well-defined crystals belonging to the cubic system, and that of these the greater number, if not all, is affected by the faces of the regular octahedron.

CHEMICAL EXAMINATION OF GOLD ORES.—A rude method of ascertaining the presence of gold in crushed quartz, or earthy ore, by washing with the hand-basin, has been described; but gold is often present in the matrix in grains or particles so minute that it cannot be detected by the eye, and sometimes it is quite disguised by admixture with other metals or minerals. Many cases occur, however, in which it is of great importance to ascertain the presence of gold, not only as a first step in the examination of suspected auriferous ores, but likewise in the assaying of alloys of gold with dif-

ferent metals. In commencing mining operations, the fact of the *presence of gold* in the ore, in any appreciable quantity, is the first point to be determined; and if this be decided in the affirmative, the next point is to determine the *proportion or quantity of gold* contained. The first process is termed *testing for gold*, or the *qualitative examination* of a suspected mineral; the second is the *quantitative examination*, or *assaying* process.

Sulphate of iron, protochloride of tin, and oxalic acid are the tests or reagents pre-eminently employed in seeking to determine the presence of gold.

Before any of these tests can be applied, the substance supposed to contain the gold must be brought into a state of solution; and this can only be done by means of the mixture of nitric and hydrochloric acids already mentioned. If the substance consist of earthy or quartzose matter, this must be reduced to powder by trituration in a mortar before it is subjected to the action of the solvent; but if the matter under examination be simply a metallic alloy, it can be dissolved without any previous preparation. An excess of acid should be avoided, and for this purpose some carbonate of soda should be added. When the solution is effected, the liquid should be evaporated to about one-eighth of its original bulk, and then diluted with three or four ounces of water. The action of the reagents is as follows:—

1. *Sulphate of Iron or Green Vitriol*.—If a few crystals of this salt be dissolved in distilled water, and dropped into the suspected solution, the result is the precipitation of the gold, if any be present, in the form of a dark-brown powder, which is metallic gold in a very fine state of division, as already described in connection with the laboratory process for preparing pure gold. If the solution has been mixed with a considerable quantity of water, the liquid, on the addition of the green vitriol, is colored brown by reflected, and blue or a dingy green, by transmitted light; and this is obvious even when forty thousand parts of the menstruum are present to one part of gold. If the liquid amount to eighty thousand parts, it is colored sky-blue; with one hundred and sixty thousand parts, it becomes violet; with three hundred and twenty thousand parts of liquid, the violet tint is still very obvious; but with six hundred and forty thousand parts, it is with difficulty perceived.

The deposit formed when the sulphate of iron is added may be corroboratively proved to be gold, by its being insoluble in nitric acid, but readily soluble in aqua regia.

2. *Protochloride of Tin*.—If to another portion of the nitro-hydrochloric solution be added a small quantity of a solution of protochloride of tin—commonly known as *salts of tin*—there will be immediately produced, if any gold is present, a dark brownish-purple precipitate, known as *purple of Cassius*. This substance is used in enamel and porcelain painting, and also for tinging glass of a fine red color, in connection with which applications it will be noticed afterwards. Its color, though not a brilliant purple, but rather a reddish-brown, is characteristic, and after being once seen is not likely to be mistaken. Its appearance, when the chloride of tin is added to the liquid, affords

an infallible proof of the presence of gold, for a very minute portion of that metal gives a manifest reaction when this test is employed.

When the first test—sulphate of iron—has been applied, and its evidence corroborated by the solution of the precipitated gold powder in aqua regia, the protochloride of tin may be employed to produce the purple of Cassius in this solution also.

3. *Oxalic Acid*.—This substance, either in crystals, or dissolved in water, causes, when added to the nitro-hydrochloric solution, the precipitation of any gold that may be present, in the form of a brown or greenish-black powder, in the same manner as the sulphate of iron; but the precipitation does not occur so rapidly. Indeed, it requires not less than forty-eight hours for the whole of the gold to be thrown down by the oxalic acid, unless heat is applied, by which the process is accelerated. The precipitate is pulverulent gold, and may be tested, as in the first case, by its insolubility in nitric acid, while readily dissolving in aqua regia. A crystal of oxalic acid, wetted with a solution of gold, becomes soon covered with a thin film of the metal, having its distinctive color and lustre.

These are the tests most easily applied by persons unaccustomed to chemical manipulation. At the same time, it may be useful to know the reactions of gold with various other substances, the most important of which, including the three already mentioned, are summarily tabulated as follows by Dr. LYON PLAYFAIR, in a lecture delivered by that chemist at the Museum of Practical Geology:—

TESTS FOR GOLD.	
Tests or reagents.	Results.
Sulphate of iron,.....	In acid solution, brown precipitate; if very dilute solution, only a blue coloring.
Protochloride of tin,.....	In dilute solution, a purple-red coloring; when strong, almost brown precipitate.
Metallic zinc,.....	Precipitates metallic gold as a voluminous brown precipitate.
Potassa in excess,.....	No precipitate; after some time a green coloring and slight precipitate.
Ammonia, ...	Yellow precipitate—fulminating gold.
Carbonate of soda, or carbonate of potassa,	No precipitate in cold solutions, but when heated, voluminous precipitate like oxide of iron.
Bicarbonates of soda or potassa,	No precipitate.
Carbonate of ammonia,.....	Behaves like ammonia, carbonic acid being evolved.
Oxalic acid,	Dark, greenish-black precipitate, more quickly produced by heat.
Tartaric acid and soda,.....	Dark precipitate when boiled.
Sulphide of ammonium, and Sulphide of hydrogen,.....	Dark brown or black precipitate.

These reactions are so characteristic that it is impossible to mistake gold for any other metal. At the same time, it may be stated that the protochloride of tin is the most infallible test, and is indeed quite conclusive. It has the advantage of being more delicate than the others—that is to say, it will indicate the presence of a smaller quantity of gold than any other reagent, not excepting the protosulphate of iron or the oxalic acid.

TESTS FOR METALS USUALLY ASSOCIATED WITH GOLD.—In examining an ore or alloy supposed to contain gold, it is often an object of great importance to determine the nature of the metals with which the gold is associated. These may be of high value on their own account, and, according to the quantities in which they are present, may greatly affect the value of the ore or mineral in question. To enter fully into this subject in connection with the rarer metals that are found associated with gold, would be of little practical use. The Editor will therefore confine his attention to the means of detecting and distinguishing those of most common occurrence—copper, silver, and platinum.

1. *Copper.*—It has been shown that copper is almost always associated with gold even in quartz, and that copper pyrites is one of those substances frequently mistaken for gold. When dissolved in acids, however, it gives characteristic actions, which render its presence easily distinguishable. One of the readiest tests is to introduce into the solution a piece of clean iron, when, if copper be present, it will be deposited on the iron in the metallic state. This experiment, remarks Dr. LYON PLAYFAIR, apparently showing the conversion of iron into copper, deceived the alchemists in their researches, and gave much support to the idea that one metal may be transmuted into another. The action depends, however, upon a simple exchange, the iron going into the solution in proportion as the copper goes out. Again, when ammonia is added in excess to a solution in which copper exists, it communicates to the liquid a rich deep blue color. Ferrocyanide of potassium produces, with copper, a brownish-red precipitate, even when the metal is present in very small quantity. Carbonate of soda precipitates copper from its hot solutions in the form of an apple-green compound, which is a carbonate of copper, known, when artificially formed, as *verditer*, and when it occurs native, as *malachite*. Copper ore in the latter form exists abundantly in Australia—not, indeed, mixed with the gold, but constituting valuable mines, from which the ore is sent over to this country, with great profit, to be smelted in South Wales.

2. *Silver.*—It has been shown that gold appears to be invariably alloyed with this metal, sometimes to a very large amount. In its separate state it is readily distinguished, not only by its white color, but also by its specific gravity, which is only 10.4, or about one-half that of gold. It may be useful to state, that when in a very fine state of division, it is of a dark-grey color. It may be easily recognized by its chemical behavior to reagents, in which respect it differs from gold by its solubility in nitric acid at all temperatures, and in boiling or heated sulphuric acid. On the contrary, with hydrochloric acid, it forms a white curdy precipitate, which is the chloride of silver. If the nitric acid employed to dissolve it contain the least hydrochloric acid, the solution will become turbid by the formation of the chloride. Hence, when a mineral containing gold and silver is submitted to the action of aqua regia—nitro-hydrochloric acid—the appearance of this white precipitate will immediately indicate the presence of the latter metal. The chloride of silver is soluble in ammonia, and may thus be distinguished from many

other white precipitates; or it may be further tested by putting the precipitate into a crucible with carbonate of soda, and exposing the mixture to a strong red heat, when a button of pure silver will be obtained. By careful manipulation the amount of silver present may be accurately determined in this manner. If the mineral containing the silver be dissolved in oil of vitriol, it is readily detected by inserting a few fragments of copper, which causes the precipitation of the silver in a pulverulent state.

From the fact that silver, in greater or less proportion, is uniformly associated with gold in the native state, it may be useful to compare the following reactions with those given in the preceding page for the metal of higher value:—

TESTS FOR SILVER.

Tests or Reagents.	Results.
Potassa,	Brown precipitate, becomes black on boiling.
Ammonia,	Brown precipitate, soluble in excess of ammonia.
Carbonate of soda or potassa,	White precipitate, soluble in ammonia.
Carbonate of ammonia,	White precipitate, soluble in excess of reagent.
Phosphate of soda,	Yellow precipitate, soluble in ammonia.
Oxalic acid,	In neutral solutions, white precipitate.
Sulphide of hydrogen and sulphide of ammonium,	Black precipitate.
Hydrochloric acid,	White curdy precipitate, soluble in ammonia.
Zinc or copper,	Precipitates white metallic silver.
Sulphate of iron,	In neutral solutions, white metallic silver.

3. *Platinum.*—This is another metal frequently associated with gold; and as it is one of the noble metals, and ranks in price between silver and gold, an ore which contains it in any considerable quantity is of great value. The specific gravity of platinum is about 21.5, and is, therefore, greater than that of gold. In short, platinum is the heaviest of all known substances. It is of a light steel-grey color, less ductile than gold or silver, but more tenacious, and will support greater weights on equal thicknesses of wire than any metal except iron or copper. It is distinguished from gold not only by its color, but also by its extreme difficulty of fusion; it does not melt by itself in the highest heat of a furnace, but softens sufficiently to admit of forging and welding, and in the arc of flame of the voltaic current, or before the oxyhydrogen blowpipe, it admits of being fused even in considerable masses. On the other hand, it resembles gold not only in its high specific gravity, as already stated, but also in the fact that it resists the action of all the simple acids, and is soluble only in aqua regia. This circumstance, together with its great infusibility, renders it importantly useful in many of the arts, and indispensable for various purposes in the chemical laboratory. It is the metal universally employed for apparatus which requires to be exposed to high temperature and powerful chemical agencies, without undergoing any change. It is, therefore, very desirable, as Dr. LYON PLAYFAIR has remarked, that those who go to the gold regions should look well for this precious metal, as it is likely to escape

the notice of the common observer from its less glittering appearance.

There are, however, certain chemical reactions by which platinum may be readily distinguished and separated from the gold in solution. Sulphate of iron and oxalic acid, which precipitate gold, do not precipitate platinum. When the latter is dissolved in aqua regia, and the acid neutralized by carbonate of soda, it is deposited as a black powder, if the mixture be boiled with tartaric acid and soda—the ingredients of a Seidlitz powder. Further, the addition of chloride of ammonium and alcohol to a strong solution of platinum, causes the deposition of a yellow crystalline precipitate, which is characteristic of this metal. These and other reactions may be summarily stated as follows:—

TESTS FOR PLATINUM.

Tests or Reagents.	Results.
Chloride of potassium or chloride of ammonium,	Yellow crystalline precipitate produced readily by the addition of alcohol.
Potassa or ammonia,	With chloride of platinum acts like the chlorides of potassium and ammonium.
Carbonates of potassa and ammonia,	In chloride solution yellow precipitate.
Carbonate of soda,	No precipitate.
Sulphate of iron,	No precipitate.
Oxalic acid,	No precipitate.
Protochloride of tin,	Dark-brown red coloring, no precipitate.
Sulphide of hydrogen and other sulphides,	Dark-brown nearly black precipitate.
Tartaric acid and soda,	On boiling, metallic platinum falls as a black powder.
Zinc,	Slowly precipitates metallic platinum as black powder.

Application of the Reagents.—Having thus described the properties and characteristic reactions of the different metals which it is desirable to look for as being frequently associated with gold, let it now be assumed that the substance to be examined is a piece of auriferous quartz. This must be first reduced to powder, and then boiled for some time in an earthenware or glass dish with aqua regia. The solution is then diluted with water, passed through a filter, and allowed to cool. If any silver be present, it will remain in the filter as a white precipitate, mixed with the quartz.

To the liquid which has passed through the filter, a solution of carbonate of soda is now added, until no more effervescence takes place. This will precipitate all the other metals which may be present except gold and platinum. These will remain in solution.

The liquid is again filtered, and a solution of oxalic acid is added until it ceases to produce effervescence, and has a sour taste; then boil; if there be any gold present, it will be precipitated as a black powder. The platinum, if any be present, will still remain in solution.

Decant or filter the liquid from the gold precipitate, and add to the former protochloride of tin, when a reddish-brown coloring will appear if platinum be present. Or, by boiling with tartaric acid and soda, the platinum will be thrown down as a black precipitate.

It has been stated that if any silver be present, it will be found on the first filter, mixed with the quartz. Wash this with ammonia, which, if copper be present, will produce a deep blue tinge. To the solution which comes through, add hydrochloric acid until the smell

disappears, and the silver will be thrown down as a white curdy precipitate.

It is evident that other methods and reagents may be adopted. For example, the original solution in aqua regia may be concentrated by evaporation, until it is very much reduced in quantity; then add about three-fourths of its bulk of spirit of wine, and, lastly, a saturated solution of chloride of ammonium. By these reagents the platinum will be thrown down as a yellow crystalline precipitate, while the solution filtered from this, and treated with sulphate of iron or boiled with oxalic acid, deposits gold.

By carefully weighing the gold obtained, the amount present in a given quantity of the ore or alloy may be exactly determined; but full details of the different methods of conducting the quantitative examination, including the assaying of gold ores and alloys by the dry process, will, to avoid repetition, be postponed to the close of the article.

GOLD-DIGGING TOOLS.—When the fact has been ascertained that a rock or soil really contains gold, and this in sufficient quantity to repay the labor of extracting it, the first operation is that of digging the soil or reducing the rock to fragments, with a view to its preparation for the subsequent processes. For the former of these purposes, the spade, the hammer, the pick-axe, and other common tools are employed; but for the special use of the gold-digger, who cannot conveniently carry a complete assortment of these, an ingenious combination of five tools, adapted for a single handle, has been contrived by Mr. T. LEE of Birmingham. Four of these are represented in the three annexed cuts.

Fig. 216.

Fig. 218.

Fig. 217.

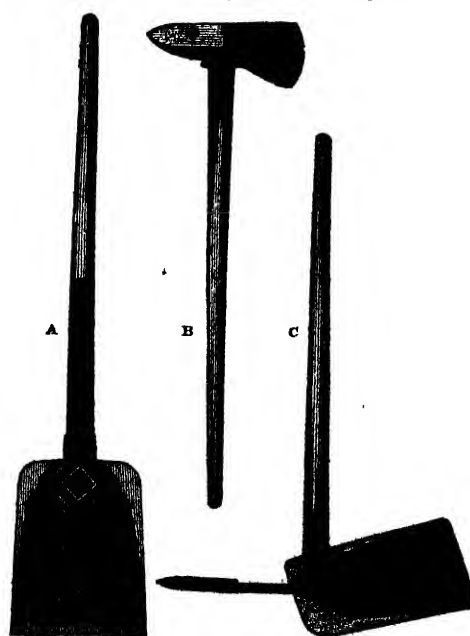


Fig. 216 is a steel shovel, with loose handle fitted to it, to suit all the varieties. Fig. 217 is the same shovel, altered for use as a pick and scraper; this alteration is effected by withdrawing the prong of the pick from a

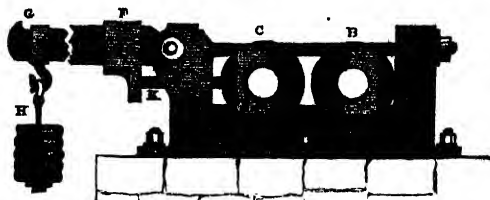
hollow socket made in the handle for its reception, and fitting the end of the handle into the eye shown in the shovel. Fig. 218 is the same handle fitted with an axe, formed with a pointed hammer, for granite-breaking. A fourth arrangement admits of forming the fifth tool, a powerful crow-bar, by fitting a short additional bar to the universal handle. Armed with this combination-tool, as the inventor terms it, the gold-digger is independent of the extensive array of ordinary implements; since, with the form of the apparatus represented in Fig. 217 on his shoulder, and the axe-head and short point of the crow-bar in his hand, he may journey freely to the scene of his operations; and when he commences work he is ably assisted by the peculiar fitness of the several combinations for the purposes of excavation. The incessant hard work of a pick rapidly wears away its point; but the combination-tool makes provision for one or more extra points to fit on the end of the pick. Those are of small weight, and may be carried in the pocket. The pick, working in conjunction with the steel plate of the shovel, which is in the position of a scraper, to remove the loosened earth, effects a saving of time, while the quick change from one tool to another causes but little delay, in proportion to the convenience secured by the great portability of the arrangement.

MECHANICAL PREPARATION OF GOLD ORES.—Before subjecting the ore, or the auriferous gangue, to the chemical or metallurgical processes by which the gold is extracted, it has certain mechanical operations to undergo, the number and nature of which will be determined by the character of the ore itself, and its state of aggregation. The metal is rarely found in the shape of large nuggets, requiring only to be cast into ingots. It is generally either in the shape of dust, or spangles, or small grains intimately mixed with the quartz rock or the alluvial soil; and though far the greatest amount of gold is obtained by the direct washing of alluvial deposits, yet, as a considerable and perhaps increasing proportion is extracted from the solid rock, it seems to be the natural order to begin with those operations by which the rock is artificially reduced to the state of an auriferous sand or pulverized ore. These operations are *crushing*, *stamping*, and *grinding*, and are usually conducted by regularly-established mining companies, while individual diggers confine themselves to the washing of soils on which the same operations have already been performed by nature.

Crushing.—To reduce the fragments of ore, as obtained from the mine, to the proper size for their subsequent mechanical concentration, it is obvious that various arrangements may be employed, although in every instance the principles involved must be very nearly the same. For this purpose, the machine represented in Fig. 219 is frequently used, and consists of two large cylinders or crushing rollers, B, C, of cast-iron, moving in contrary directions in a strong iron framework, A A, secured to a solid wooden frame by means of screw-bolts. The bearings, D, E, of the rollers are so arranged as to slide in grooves, and consequently admit of the cylinders being either brought nearer to each other or separated to a greater distance. To admit of

the passage of large pieces of stone too hard to be broken, a certain elasticity is given to the machine by means of the lever, F G, which, by a sliding bar, and

Fig. 219.



the shoulder, K, constantly tends to keep the surfaces of the two grinding cylinders in contact, being loaded at its extremity with a heavy weight, H, which is adjusted to the hardness of the mineral to be broken.

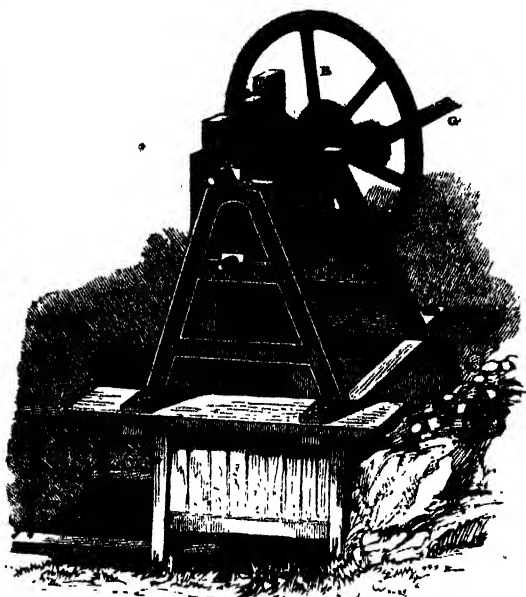
After passing between the rollers, the crushed ores fall into the upper end of an inclined cylinder of coarse wire gauze, similar in construction and operation to that which is described in Vol. I., p. 169, in connection with the alum manufacture, and is there represented on the right hand side of Fig. 97. This cylinder receives an oscillatory motion from the same steam or water power which impels the rollers, and divides the pulverized ore into two classes; that which passes through the meshes of the gauze falls on the floor of the building, whilst those grains which are too large to pass through the sieve are carried out at its lower end, and fall into the buckets of an endless chain, by which this portion is again brought to the level of the hopper over the rollers for the purpose of being subjected to another crushing.

Stamping.—When the ore is required to be reduced to a finer state of division than can be readily effected by means of the crushing rollers, it is usually subjected to the pounding action of large wooden pestles, armed with iron heads, and moved either by steam or water power. The vertical wooden beams of which the pestles consist, are placed in a row, and are successively raised by cams fixed around a movable axle, so as to correspond with tongues attached to the pestles themselves. The cams are so arranged in three spirals that each pestle shall give three blows during each revolution, and as soon as the first in the series has been released from its cam, and begins to fall, the second cam of the same spiral comes in contact with the tongue of the next pestle; and so on until each has successively struck a blow, when the first pestle is again caught by the first cam belonging to the second spiral, and another series of rapid blows is given. The size of the iron stamp-heads varies according to the nature of the mineral to be broken; but their general weight is from three hundred to four hundred pounds.

In some of the more modern stamping-mills, both the axles and pestles are of iron; and a great improvement in the method of lifting the pestles has been recently effected by Mr. WALKER, of London, who substitutes a series of endless chains for the axle, and thereby increases the height of the fall of the pestles to any required extent. This arrangement is shown in Fig. 220, where A A A represent three of the pestles, while the top of the fourth is nearly on a level with the

collar through which they pass; and B denotes the endless chains revolving on the axles, C, D. When motion is given to the machine, the pestles are successively

Fig. 220.



raised through the whole distance from C to D, by projecting links on the chains, which are caught by tongues on the pestles, and these tongues are so arranged that each of them may in rotation be raised and released, as in the case of the spirals already described. A rapid succession of blows is thus struck; and each of the pestles when released falls on the mineral placed below with its whole weight, to which much additional force is given by the impetus acquired in descending through the space, D C.

In Mr. WALKER'S arrangement, as in the older stamping-mills, the minerals to be pounded are placed in a large wooden trough, in which are openings provided with sieves, or strainers, made by punching small holes in thin sheets of iron. The pulverized ore is carried through these sieves by a current of water admitted into the trough, which is then conducted over an inclined table, F, set in motion by the chain, E. The heavier and richer portions accumulate on this table, whilst the lighter are washed away into a series of reservoirs, in which they subside in the order of their specific gravity. The machine may be worked either by the hand or by steam or water power.

Grinding.—If it be deemed desirable to reduce the ore to a still greater degree of fineness, any form of apparatus, commonly used for grinding, may be employed. In Mexico the sands obtained from the stamping-mills are afterwards ground, with water, in a machine similar to the common mill-stone. Edge-stones, resembling the apparatus represented in Vol. I., Fig. 97, are also employed for the same purpose. It is necessary, however, that the grinding-mills be either of iron or granite. In the stamping-mill, the ore is already reduced to the state of sand; and, therefore,

the further pulverizing, if thought necessary, is usually associated with the operations of washing and amalgamating.

Washing.—It has been stated, that the greater portion of the gold is obtained from the alluvial soils or sands, on which nature has already performed the operation of crushing or pulverizing the rock. In general, therefore, the washing process is that with which the gold-digger commences; and this, indeed, together with the labor of extracting the soil from the pit, or from the bed of the stream or river, is the only operation usually resorted to for procuring the gold dust or nuggets which are sent from Australia and California. At the same time, the further process of amalgamation, when it can be conveniently employed, extracts the auriferous particles more thoroughly. These two processes—washing and amalgamation—which now remain to be described, are equally applicable to the pounded or pulverized rock, and to the auriferous soils which constitute at present the chief source of the supply of gold. The absolute necessity of washing the soil, to procure the precious grains, even when amalgamation is subsequently resorted to for more effectually extracting the metal and removing impurities, teaches the great importance of opening the pits or diggings in a situation where an ample supply of water can be obtained.

Hand-Washing.—The operation of hand-washing, which is the simplest method of separating the gold dust or grains from the soil, in a state of greater or less purity, has been already described. This method is extensively practised in South America, and the instrument employed is a round iron or zinc pan, Fig. 221, shallow at the sides, but sinking into a deep cavity in the middle, where the heavy particles of the gold accumulate, during repeated washings, which carry off the earth or stony matters. The gold is still mixed with impurities, from which it is ultimately separated by amalgamation.

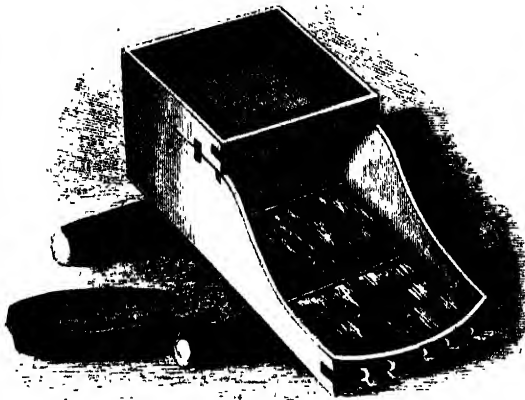
Fig. 221



The Cradle.—Next in point of simplicity to the pan or basin, is the cradle, or rocking machine, which is much used in Australia and California, and is so named from its resemblance to the common article of domestic furniture. It consists, as shown in Fig. 222, of a wooden or tin trough, six or seven feet in length, under and across the bottom of which two curved bars of wood are fixed, to serve as rockers. Sometimes it is suspended by ropes from a cross-bar, supported at each end by two poles. The cradle, whether suspended or resting on the ground, is made to have a slight inclination from one end to the other, to allow the water to run off. At the upper end is placed a sieve, or coarse grating, on which the sand to be washed is charged; and the interior of the bottom of the vessel is provided with a few transverse bars, to arrest the heavier particles in their descent, while the water and lighter matters flow off. Four men are required to work this apparatus efficiently—one to dig and collect the auriferous sand, another to carry it to the cradle, and deposit it on the grating, a

third to rock the trough, and a fourth to attend to the supply of water, and the uniform washing of the material. The grating intercepts the stones and coarser

Fig. 222.

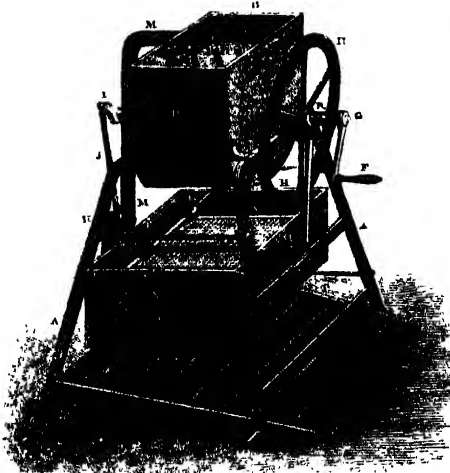


gravel; the earthy matters, containing the particles of gold, pass through; and the latter, with the heavy ferruginous sand, are arrested by the transverse bars, while the lighter portions are carried down by the water to the lower end, which is left open, or where a perforation is made to allow the current to escape.

After continuing the operation, with repeated charges of the auriferous sand, during a sufficient period, which will vary according to the richness of the material, the concentrated ore which has accumulated behind the bars of the cradle, is collected in a tin pan, shown in the same figure, and after being dried in the sun, the lighter impurities still remaining are removed, by blowing strongly on the mixture with a pair of bellows or otherwise.

Gold-Sifter.—A more refined apparatus, for washing and sifting the auriferous ore, which was registered by

Fig. 223



Messrs. LAMBERT and DANBY of Liverpool, is represented in Fig. 223. It consists of an open frame, A A, carrying a receiver, B B, in which is a revolving barrel, set with a series of pins, D, working in gear with other

corresponding pins, which are made fast in the receiver. The pin-shaft, G, which carries a fly-wheel, H H, is driven by the winch F. The other end of the shaft works a crank, I, from which a connecting-rod, J, passes down to a pump, K, for supplying water through the pipe, M M, to the working-chamber. Beneath the latter is a box, containing three separate sieves, N, O, P, of graduated fineness, and made to oscillate by a lever arm at Q, acted on, through a rod, S, by an eccentric, R, on the shaft, G. At the foot of the frame is an incline, T, for running the water away into the reservoir—strips of wood being set across it, to arrest any small particles of gold which may escape through the last sieve. At U is a valve, beneath the receiver, B, for discharging the agitated mass upon the sieves.

This is a very complete and easily-worked machine. By the simple turning of the winch handle, not only is water supplied in abundance, either from a river or cistern, but the mass is well comminuted, intimately mixed with the water, and reduced to an impalpable slime by the action of the pins, D; so that when accumulated in sufficient quantity to force a passage through the valve, U, the great body of the mixture readily passes through the sieves, and flows away into the reservoir, leaving only the grains of gold and other hard substances which cannot penetrate the meshes, while the finer particles of the precious metal, or what may be termed the gold dust, collect by their superior gravity behind the transverse bars of the incline, T. The series of graduated sieves is important for assorting the particles of gold, and the stony or earthy matters with which they are mixed, into grains of different sizes—the product or contents collected in each sieve being nearly uniform. This greatly facilitates the ultimate washing; for when the grains of an auriferous mixture are of different sizes, the smaller surface of one fragment, in proportion to its weight, compensates in some measure for the greater density of another grain, and thus causes it to assume a position in the series of deposited layers, to which, by its constitution, it is not entitled. This difficulty is found to constantly occur in practice; and it is with the view of obviating it as much as possible that care is taken, in the best machines, to separate, by means of sieves, into distinct parcels, the fragments which have nearly the same size.

Methods of Washing in Brazil.—In Brazil, the excavations and river-washings are entirely conducted by negroes, who are furnished with a large wooden bowl, about two feet in diameter, and nearly one foot in depth; as also with a leathern bag, which is tied before them, for the reception of the particles of gold dust collected, after repeated washings, in the bottom of the bowl. Sometimes, however, the final washing of the auriferous sands is conducted in long shallow troughs, the bottoms of which are covered with coarse baize, or with skins tanned with the hair on, and placed with the grain against the current of water. The baize, or skin, is at short intervals removed from its frame, and beaten over a shallow tank, containing water; it is then carefully washed in the same vessel, until every particle of the gold is removed, after which it is replaced in the trough for receiving the auriferous sands, already partially washed. To obviate the inconvenience of so frequently

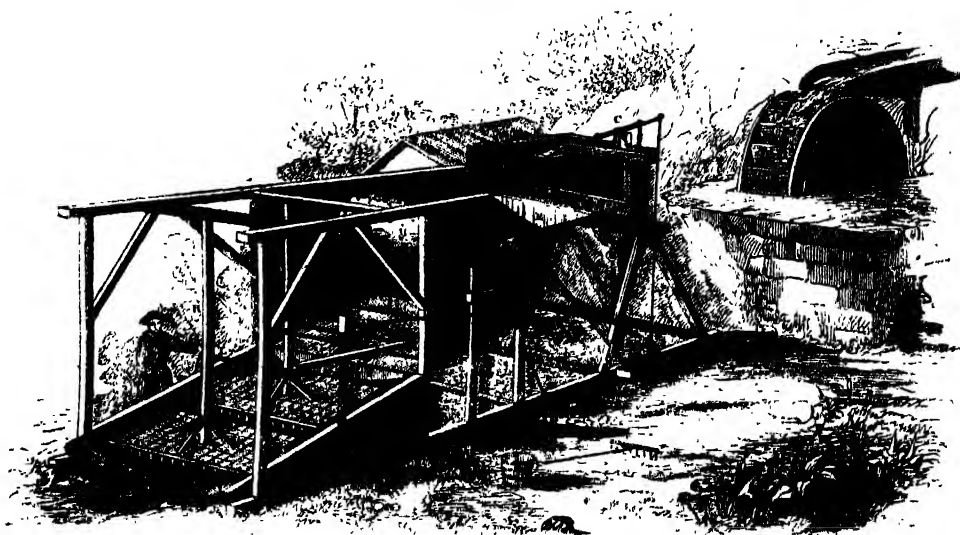
removing the skin or cloth from the vessel in which the washing is conducted, an endless web of the same material has lately been introduced, which is made to move by means of rollers impelled by the water-wheel employed for stamping the ore. The motion communicated in this manner is opposite to that of the stream of water flowing over the table; and while the upper portion moves upon this table, extended between the two rollers, collecting, in its progress against the stream, the particles of gold, the lower or returning portion hangs down loosely, and is drawn through a vessel of water, in which the gold is washed off and collected.

Methods of washing in Hungary and the Ural.—In Hungary and the Ural the methods of washing are various, but the principle generally adopted is that of inclined troughs or tables, traversed by transverse grooves—a principle adopted in the cradle, and almost all other washing-machines. On the large scale, however, these inclined tables may be compared to the apparatus for washing coal, represented in Fig. 74, at page 95 of this volume. The sand to be washed is placed in the

first groove of the series, and is there exposed to a current of water, until the gold, mixed with a portion of ferruginous sand, alone remains in the furrows. The concentrated ore is then removed into flat wooden basins, in which the impurities are gradually separated by repeated washings, or these may be removed at once by amalgamation.

Among the different methods adopted in the Ural districts, there is one by AGRI, in use at Alexandrowsk, which is precisely similar in principle to that above described, though somewhat more complex in the arrangements. These are represented in the annexed engraving—Fig. 224—where B is a conical cylinder of sheet-iron, about eight feet in length, and having a mean diameter of about three feet six inches. This cylinder is pierced with holes of about half an inch in diameter, and is fixed on a spindle communicating by a train of wheels and shafts, with a water-wheel, horse gin, or any other prime mover, from which it is capable of receiving a rapid rotatory motion, so as to make from thirty to forty revolutions in a minute. A crank on

Fig. 224.



the shaft which communicates motion to the cylinder, works the double pump, c, at the back of the frame, which raises water from a well or some other convenient reservoir to the cistern, D, and from this it is conducted by pipes into each end of the cylinder, B. The ends of the cylinder are open, and the pipes are so arranged as to diffuse the water pretty equally over its interior surface. Nearly on a level with the top of the arrangement is a line of rails, on which the auriferous sands are brought in wagons to the hopper, E, from which they fall into the smaller end of the revolving cylinder. The latter by its centrifugal action ejects through its numerous perforations the water and finer particles of sand and gravel, which are received upon the inclined platform below, whilst the larger fragments are carried down to the under end of the cylinder, and there fall into a box which does not appear in the engraving. Any gold nuggets which may be mixed with these fragments, being well washed and burnished in their

gradual progress through the cylinder, are now readily perceived and picked out. The platform, which receives the water and auriferous sand expelled through the holes in the cylinder, is provided like the cradle, the sifter, and the arrangement last mentioned, with numerous cross bars, for the purpose of checking the current, and arresting the heavier particles of the ore; and after traversing this platform, the current descends to a concave table or tye, c, which is also furnished with a series of wooden bars, at intervals of two or three feet. The sands which have arrived at this part of the machine are kept constantly stirred or agitated by square frames carrying blunt iron knives, and suspended, pendulum-wise, by vertical bars, H H, from a wooden axis above the tye, turning on gudgeons, and placed in the direction of its length. The frames are made to fit into the cavity of the tye, and a swinging alternating motion is given them by means of the rods, L L. In this way the sands are well stirred; and while the heavier or

richer portions are retained and accumulated behind the check-boards, the lighter materials are carried away with the current at the lower end, *G*, of the tye or buddle, from which, if not sufficiently impoverished, they are received on a fresh series of tables, furnished with similar agitating apparatus, and are finally allowed to pass off. This machine is able to operate on two hundred tons of alluvial sand in the course of an ordinary working day of ten hours, with the labor of twenty men and six boys, including ten men for removing the waste, if in a level country, without advantages for otherwise clearing it away.

The partitions in the bottom of the tyes are ribs of two inches high and two and a half inches wide, held by screw-bolts and nuts, and are removed every now and then for the washing out of the concentrated auriferous sand. This is done the more frequently in proportion as the sands are richer in gold.

Fine Washing.—The gold obtained from all the preceding operations, is still so much mixed with sand and other substances, as magnetic iron, pyrites, *et cetera*, that it requires to be further concentrated, either by additional washing or by amalgamation. The powder collected in the buddles or tyes is commonly of a grey color, and is termed *grey schlich*. By the cylindrical machine above described, the original ore or auriferous sand is concentrated to about three tons of *schlich* for every two hundred tons of the crude material employed. For its further cleaning and concentration by washing, it is treated on uncovered tables or frames, seven to ten feet long, by three or four broad, and divided into an upper and lower part by a lath nailed across the bottom. Also, across the upper part, are fixed two boards, which regulate and equalize the flow of water. The *schlich* to be washed is placed upon the upper division, and the workman, standing upon the frame in wooden shoes, mixes the sand with the water, and gently moves it against the current, towards the head of the arrangement, with a small wooden hoe or heath-broom. The gold thus arranges itself chiefly near the head-board, and when a certain amount is collected, he rakes it with his hoe or broom, just strongly enough to draw down the earthy particles over the lath to the lower division, without disturbing the heavier and richer deposit. This delicate operation requires skill and dexterity, and must be continued till all the coarse fragments are removed, after which the flow of water is reduced. The workman, by light brushing, raises again all the slime which may still remain, and as much as possible of the magnetic iron ore, and takes up as the product of his manipulation the *black schlich* which is left. The upper department of the box being thus cleared, he now brings upward that which has settled in the lower part, and passes it once, twice, or thrice, through the same operations. This process, for which the most skilful and experienced workmen are required, is termed *fine washing*. The *black schlich* or ore thus concentrated is dried, and is freed from a further quantity of magnetic iron, by the use of an artificial magnet or a piece of loadstone.

The *gold-troughs* used in Hungary and Transylvania for the final washing of the powder or *schlich* obtained from the cloth-covered tables already alluded to, as well

as the process of washing, are similar to those just described. In these countries a broom of heather or birch is generally used instead of the hoe; and in Transylvania the troughs, which are of larger dimensions, are fitted with two traps in their channels, into which the different qualities of *schlich* are swept at different stages of the process. Even after this fine washing, the resulting products are sometimes further concentrated in the bowl or washing-pan, and so reduced to a state fit for melting, or they are subjected to the process of amalgamation.

AMALGAMATION OF GOLD ORES.—The greater part of the gold of commerce is imported in the shape of dust, or small grains, extracted from the auriferous soil by the simple washings above described, and brought, by a frequent repetition of that process, to a state of sufficient purity to be immediately melted into ingots, more or less mixed with silver or copper. Sometimes, however, instead of the tedious process required to bring the gold by mere washing to that degree of concentration which is necessary for its subsequent fusion, the purification of the gold by this method is only carried to a certain point, and the operation is concluded by amalgamation, or, in other words, by mixing the partially-concentrated ore with mercury, which seizes on the particles of gold, and thus completely separates and extracts the precious metal from the soil or gangue in which it is found.

It may be laid down as a general rule that amalgamation would be advantageously resorted to in all cases, as the finishing process in those operations which precede the metallurgical treatment of gold. By no other method can the precious metal be thoroughly extracted from the gangue, and so effective is its action, as compared with mere washing, that it has often been applied with success to extract a remunerative return from the refuse or waste sands which have passed through the gold-digger's cradle. Its profitable application, however, will depend on the nature and richness of the auriferous soil. If the gold is abundant, and is found in considerable grains, as in many parts of the recently-discovered gold regions, the greater and most valuable part of it is readily separated, and easily concentrated sufficiently by mere washing. On the other hand, if, as often happens, the gold is diffused through a dense and heavy gangue, in particles so minute as to be invisible to the unassisted eye, it is evident that these particles will float away with the current when the sand or crushed ore is washed on inclined tables, and that their extreme minuteness will counteract the effect of that difference in specific gravity by which it is so easy to separate the larger grains when diffused through a less dense soil. On the whole, therefore, while amalgamation must be applied in all cases where it is desired to extract, practically, the whole of the gold, it is more especially applicable to its extraction from quartz rock, from heavy pyritous ores, and from other descriptions of gangue, through which it is diffused in a state of extreme division. And as the mercury exerts no chemical action, but may be again separated from the gold with little loss, the advantages afforded by the great efficiency of this process are not materially restricted by economical considerations.

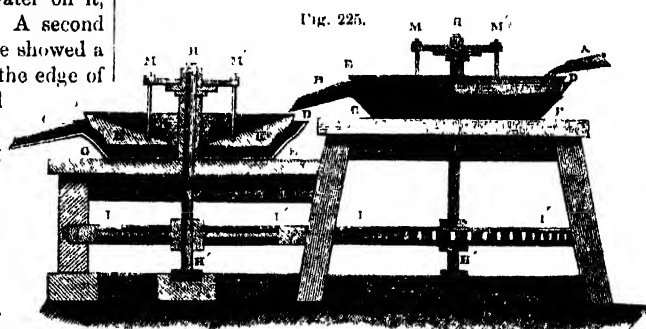
From the nature of the ore which is usually treated by amalgamation, this operation is generally associated with the preliminary processes of stamping or grinding, as well as partial washing. One of the simplest and most primitive methods adopted is described by Mr. W. B. ADAMS as having been witnessed by himself, in the course of a week's trip which he made with a South American *cateador* or gold-mine hunter, for the purpose of acquiring information. When the travellers had passed the extreme limit of vegetation, and entered a narrow ravine between lofty ridges of hills, the *cateador* began to examine carefully the stones at his feet, which became more and more abundant, till nothing was seen but clay-slate shingle. On the second day, after turning up another ravine, he picked up a stone, which he examined with some attention, and then went on. About mid-day the travellers stopped, and the gold-hunter picked up a fragment of quartz from amidst a great variety of stones. He then placed it on a flat piece of rock and pounded it, and ground it to powder, which he placed in a horn, and poured some water on it, shaking it about with a peculiar motion. A second and a third water were added, and finally he showed a fringe of fine gold on the black horn, along the edge of the quartz sand. No vestige of gold could be observed in the quartz before grinding. Satisfied with the result, he went on tracking the fragments of quartz, till at last the travellers came to the vein, in granite rock. He selected a few pieces, which he put in his wallet, then piled up some stones to mark the spot, and they set out on their return home. In a neighboring valley, he exhibited his stones to a proprietor, whose business it was to extract gold from quartz, and sold him his discovery for the sum of twenty-five dollars.

The mode of extracting the gold was very simple, and is thus described. A vertical running-stone traversed in a circular stone trough. Quartz, broken to the size of walnuts, was thrown into the trough, with several pounds of mercury. A small stream of water trickled into the trough, and flowed over at a particular spot, carrying with it the finer ground particles. At the depth of a foot it fell into a goatskin bag, with some quicksilver in it; thence into a second, third, fourth, and fifth bag, as long as any fall could be obtained. After working several hours, the mill was stopped, and all the mercury collected in a long narrow linen bag. Into this it was forced with a stick, and then the bag was squeezed till all the uncombined mercury passed through, and only the amalgam of gold was left. This was placed on a piece of strongly-heated iron, resting on a brick standing in water. An earthen cupola was laid over the whole, forming a water-joint at bottom, and the neck of the cupola descended into water. Thus the fumes of the mercury, sublimed by the hot iron, were condensed and collected in the water, and the metal saved. The spongy gold, called *pine-gold*, was left on the iron plate.

In Piedmont, where veins of auriferous pyrites have been worked from a very remote antiquity, the extraction of the gold is effected almost entirely by amalgamation. The produce is very variable in different

localities, but averages about twenty shillings in value from 150 pounds avoirdupois of the auriferous ore. The amalgamating mills are erected in great numbers on the banks of the various rivulets which traverse the mountains. These establishments usually consist of small wooden buildings, each of which contains four amalgamating machines. They are erected at intervals over the whole length of the valley of Anzasca, from Chamnaga to Pie di Mulera; and in this valley there are more than two hundred mills procuring a remunerative return from a very poor soil, by the process of amalgamation.

The ore or mineral, when extracted from the mine, is first subjected to a grinding or triturating process in a machine resembling in its action and operation the common millstone, and driven by a water-wheel. When thus reduced to powder, it is carried off by a stream of water to the amalgamating mills, represented in Fig. 225. Whilst held in suspension in the water, it is conducted first to the upper mill by the spout A, from



this to the second by the spout B, and so on in succession through the whole series. Each mill consists of a cast-iron basin, D E G F, fastened by screws to the top of a strong frame or table, and fitted in its centre with a tubulature, traversed by the axis H H', moved by the toothed wheel I I', and with which revolves a wooden muller, K K, fixed to the upright spindle by the iron collar M M'. This movable part of the mill has externally the same form as the internal cavity of the fixed iron casting, G, in which it revolves horizontally, at the distance of about half an inch from its surface; at the same time it is furnished with several iron ribs, which come nearly in contact with the interior of the casting. The rotating muller is made of hard wood, and is hollowed out like a funnel, in which the auriferous slime accumulates, and gradually penetrates into the interval between its external surface and the bottom or interior surface of the iron basin, from which it flows to the next mill by the spout B or C.

In the bottom of the fixed vessel is put about half a hundredweight of mercury, which lies to the depth of about half-an-inch, and when the machine is set in motion, the pounded mineral is constantly agitated and mixed with this fluid metal by means of the iron ribs nailed to the bottom of the muller. The minute particles of gold are thus immediately dissolved and taken up by the mercury, while those which escape combination in the first mill are arrested and retained by the second, third, or fourth of the series.

After working the mills continuously for several weeks, the time required being longer or shorter according to the richness of the mineral under operation, and when the mercury is judged by the workmen to be sufficiently charged with the precious metal, the mills are stopped, and the amalgamated mass is taken out. It is important not to protract the process unnecessarily, otherwise a serious loss of mercury is sustained, occasioned, perhaps, by its partial conversion into a sulphide, which is carried away with the current. The mercury, when drawn off, is washed, and then strained or filtered through a piece of chamois skin, for the purpose of obtaining the solid amalgam, which usually contains about one-third of its weight of pure gold. This is separated from the combined quicksilver by distillation in an iron retort, the beak of which dips into a vessel containing water. The whole of the mercury in actual combination with the gold is thus recovered, and the only loss sustained is that which has been carried away by the current in the shape of sulphide and otherwise. DUMAS states that the loss incurred in this manner is equal to about one-fourth of the quantity employed; but so large a waste must result from careless manipulation.

In the Salzburg Alps, the gold ore is worked in lodes or veins, and the precious metal is separated by three processes—washing, roasting, and amalgamation. It is chiefly in actual *mining*, not in what is popularly known as *digging*, that the latter two operations are brought into requisition. The mineral extracted from the lodes, in the locality above-mentioned, is divided into two classes or qualities—first, that which is so poor in the precious metal that the grains or particles are not visible; and, second, that in which the golden grains may be detected. Both are crushed or stamped; but in treating the former this operation is preceded by roasting, to facilitate its pulverization under the action of the stamps. This roasting, though not practised at all the mining establishments, is useful, not only for the purpose above-mentioned, but also for converting the sulphides and arsenides into fine light oxides.

The mineral, whether roasted or not, having been passed under the stamps and well ground, is washed first on movable inclined tables, and then in wooden hand-bowls. The gold is thus obtained in a state of considerable concentration, and then the work is completed by amalgamation. In the Salzburg country this last operation is conducted in a peculiar manner, and requires a machine constructed with much care, somewhat resembling in its principal parts the common flour mill. The upper mill-stone revolves horizontally in a hollow cylinder, and over it is placed a hopper, which can be depressed or elevated at pleasure. The object of this hopper is to spread over the mill-stone a uniform layer of mineral. Below are placed three iron cylinders, in which the amalgamating mills revolve, with their axes resting on bearings which admit of being raised or depressed according to the nature of the mineral under treatment. Water is admitted by a stopcock into the upper mill, where it is intimately mixed with the mineral into a slime or paste, and from this it descends to the amalgamating mills by an inclined plane terminating in three pipes or gutters, which

divide it equally between the three cylinders. From these the fluid amalgam is conducted by a second inclined plane to a washing apparatus.

The process begins with pounding and washing. The mineral, thus pulverized and partially concentrated, is then mixed with a certain quantity of chloride of sodium and thrown into the hopper, from which it descends over the inclined plane into the hollow cylinder containing the large mill-stone. When the hopper is emptied of the first charge, more mineral is poured in till the upper cylinder is full, and then water is admitted, which carries the auriferous slime, so formed, over the second inclined plane into the three amalgamating mills below. Before introducing the quicksilver into the cylinders containing these mills, the machine is allowed to work on the mineral for the space of two hours; the mercury is then added, in quantities of about fifteen to eighteen pounds at a time. The quantity of mercury, water, and mineral introduced should be in the proportion of fifty, thirty, and one hundred; or, in other words, *for every hundred pounds by weight of the mineral, there ought to be fifty pounds of quicksilver, and thirty of water.* In some establishments, a quantity of mercury equal in weight to that of the mineral is introduced, and the work proceeds with all the greater certainty, although the waste or loss of mercury sustained may in this case be more considerable.

In this operation the amount of water introduced is not a matter of indifference. If it be too small, the mixture will be pasty, the motion of the mill will be obstructed, and the ore will adhere to the sides of the cylinders, without undergoing amalgamation. If, on the contrary, the mixture be rendered too fluid, the particles of gold and silver, which are generally found together, will be carried away too rapidly, and in this case also will escape combination with the mercury.

On the other hand, it is evident that an adequate supply of the fluid metal is a point of the greatest importance, as it acts on the gold only in proportion to the extent of surface which it exposes to the mineral. To enlarge this surface, the vessels in which the amalgamation is conducted have latterly been formed like an inverted cone, terminating in a hollow sphere. It is with the same object in view that a rotatory motion is given to the mass; for the centrifugal force thus communicated raises the mercury against the sides of the cylinder or cone, which widens or expands upward so as to increase the extent of surface exposed, and then the mercury falls back again into the mass by its own weight.

Although the numbers given above may convey a general idea of the proportions of the three ingredients to be employed, it deserves to be remarked, that these must be varied according to the nature of the mineral under treatment, and that indeed the quantity of mercury should be proportioned rather to the bulk or volume of the ore than to its weight. The lighter the ore, the more space will it occupy in the cylinders; and as the mercury should rise over the mass, more of it will be required in this case to insure its union with the gold or silver present. If the mercury be in small quantity, the amalgam is not sufficiently fluid, and is partially converted into a dust or

frothy substance, which flows away with the water when the latter is allowed to escape from time to time, so that a considerable loss is sustained both in gold and quicksilver. If, on the contrary, the quicksilver be present in excess, the gold combines with it more rapidly and more thoroughly; the amalgam remains fluid, and readily separates from the other materials with which it is mixed. It is therefore by no means economical to stint the supply of mercury.

There are some indications by which a judgment may be formed as to whether the mill is operating in a satisfactory manner. If particles of gold, not amalgamated with the mercury, are observed in the cylinders, this is a proof that the millstone is too high, and does not come into close enough contact with the mineral, in which case the mercury, not being agitated, remains inactive at the bottom of the vessel on account of its superior gravity. If, on the contrary, a quantity of quicksilver-dust and frothy amalgam be observed on the cylinders, this is an evident sign that the former has ceased to absorb the gold, and that more must be added.

It usually requires about sixteen or eighteen hours to complete the amalgamation. The final washing is then proceeded with, and is effected by a current of water, which carries away the earth, and purifies the amalgam from those substances not combined with the mercury. This operation is performed in a wooden vessel of a conical form, the bottom of which slopes to the centre, and is fitted with a stopcock. A circular movement is given to this vessel, that the mass may be kept in a state of agitation, and the lighter parts carried away by the current of water admitted, while the amalgam falls by its own weight to the bottom of the vessel. This operation is repeated several times.

When the washing is concluded, the next and last step in this process is the separation of the mercury. With this view the liquid amalgam is put into a chamois-skin or woollen bag, and well squeezed. The mercury which passes through the skin or cloth, still retaining a small quantity of gold, is carried back to the cylinders to be employed in amalgamating the next charge. There remains in the bag a semi-solid amalgam of gold, which is put aside for distillation. By wetting the bag which is to be used for straining, a larger amount of amalgam remains, and the mercury which passes through carries with it less gold. When the solid amalgam is very pure, it is rather white in color; but when alloyed with lead or copper it is less so, and does not produce the same crackling noise when crushed or broken. The amalgam, as in the other cases already mentioned, is deprived of its mercury by distillation; or, if a small portion of that metal still remains, it is expelled in the subsequent fusions to which the gold is subjected with a view to its final purification.

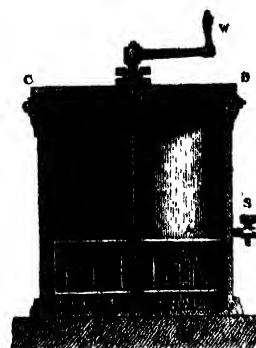
The preceding process, which is practised, as already stated, in the Salzburg Alps, presents some peculiarities. The amalgamating mills are somewhat similar to those employed in the Tyrol, but these mills are fed in a different way, and a larger proportion of mercury is used. The last circumstance is highly advantageous, and ought to be imitated in all cases where the nature

of the gangue, or mineral under treatment, will admit of it; for, with an ample supply of quicksilver, the extraction of the gold is not only more rapid, but more complete. But, with a strongly pyritous gangue, like that of most of the Piedmontese mines, the employment of a large excess of mercury would seem to be productive of a heavy loss of that metal arising from its conversion into a sulphide.

For effecting the amalgamation of the concentrated auriferous ore or black schlich by manual labor, the machine represented in Fig. 226 is sometimes employed.

This consists of a species of churn, *v*, made of sheet-iron, through the lid of which passes a spindle, *x*, of the same metal, carrying a kind of paddle-wheel, *A*, which is turned by the winch-handle, *w*. The bottom of this machine is first covered to a small depth with mercury, and then the concentrated ore is added by an opening at the top in successive small portions, while, at the same time, the whole mass is continually agitated by stirring; and this process is continued till the mercury is judged to be sufficiently saturated with the gold. The amalgam is then taken out and treated in the usual manner, by washing, straining, and distillation.

Fig. 226.



It may be stated that the same apparatus is highly convenient for the original washing or concentration of the ore, or auriferous sand, and, when employed for that purpose, is familiarly known as the *dolly-tub*. In this case it is nearly filled with water; and whilst one man keeps the agitator in constant motion, another throws into it, in small portions at a time, the auriferous earth. When the full charge has been thus introduced, the cross-bar, *B C*, through which the spindle works, is removed, and the agitator is quickly taken out. The materials held in suspension are then allowed to settle according to their respective gravities, and, consequently, the gold, together with all the heavier particles, will sink to the bottom. When these have subsided, the water is drawn off by the stopcock, *s*; the upper portions of the deposit are cautiously removed and thrown away, while the heavier portions at the bottom are collected for further concentration, either by the hand-bowl or otherwise. But although the *dolly-tub* may thus be applied to the double use of a washing and amalgamating machine, it is less convenient for the former purpose than the cradle, and other kinds of washing apparatus already mentioned.

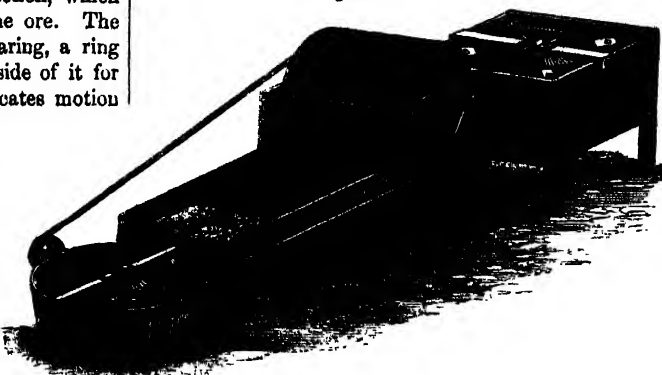
Another machine, which is easily worked by the hand, was contrived by Mr. BERDAN of New York, in the heat of the Californian mania, and is known as BERDAN'S Gold Ore Pulverizer and Amalgamator. In this machine, the pulverizing process is effected in a large hemispherical iron vessel, rotating on an inclined spindle, and having within it a weighty iron sphere, connected by a pivot and bearings set in an inclined

position loose upon the central spindle of the basin, in such a manner that its gravity causes it constantly to maintain the lowest possible position in the basin, whilst its axis of rotation, owing to the pivot connection, is inclined to that of the basin. The motion thus communicated to the sphere is not a mere rolling, but a species of spiral action, which is said to be very effective in reducing the ore. The basin is made to revolve by suitable gearing, a ring of teeth being cast or fitted on the outside of it for this purpose, and its revolution communicates motion to the sphere. A quantity of mercury is placed in the bottom of the basin, and the ore is reduced to powder entirely beneath its surface, being latterly washed away by a current of water which runs into and out of the basin, and is kept in a constant state of agitation by the motion of the vessel. As heat considerably strengthens the affinity of the mercury for the gold, a new and important feature was introduced into this machine by the employment of a furnace in connection with the apparatus. This furnace or fire-place is of a conical shape, and rests by its lower smaller end on a collar upon the basin-spindle, just above the step. It was stated, though probably with much exaggeration, that while the machines previously employed extracted only from thirty to forty per cent. of the gold in a given quantity of quartz, the most searching chemical analysis was unable to detect any gold remaining in the *tailings* or waste matter from Mr. BERDAN's machines, and that these, moreover, were very profitably employed in re-working the tailings from other machines. It does seem probable that the introduction of a furnace to heat the mercury might greatly increase the efficiency of this apparatus, and that the same improvement might be applied with good effect in other machines. At the same time, it is obvious that if caution is not exercised to prevent the heating of the mercury beyond a certain point, a very great loss must be sustained by its volatilization.

SMITH's Portable Gold Amalgamator, which is represented in perspective in Fig. 227, also admits of being worked by the hand, and is designed for the use of emigrants, and the proprietors of mines and estates where gold may be supposed to exist. This machine is divided into three compartments. In the first, A, are arranged a set of powerful crushers, and a series of agitating plates, intended for stiff and hard clays; two, or three revolutions reduce the matter to a floating pulp, which flows off through a pipe, D D, leading from this part of the machine to the amalgamator, C. The pipe is provided on its lower side with a series of boxes or valves, which can be opened or shut at pleasure, and only that portion of gold passes on to the amalgamator which cannot be detained in these valves. The second compartment, B, is constructed for the reception of the looser earth, and consists of a drum or barrel in which revolves an agitating apparatus. Nothing is allowed to leave this until it is perfectly worked, when the opening in the side of the barrel is turned downward, and all stones and other foreign matters are dis-

charged into the chamber beneath, in readiness for receiving a fresh supply of the auriferous earth. The chamber into which the contents of the barrel are thus discharged is relieved from time to time by raising a sluice; and the floating matter then passes over a long

Fig. 227.

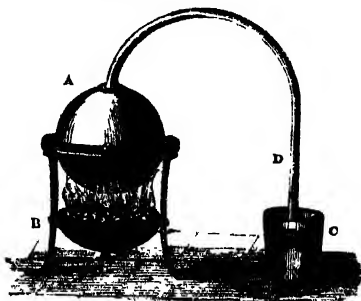


trough; B, provided with check-bars, to empty itself into the amalgamator—all solid particles being, in this case also, arrested in their passage from the washer, while, by a simple arrangement which it is unnecessary to detail, the action of the machine keeps up a constant supply of water. The third portion, C, of the machine, or that compartment which is properly the amalgamator, is so constructed as to expose a large surface of mercury to the action of the floating matter, and by means of washers and balls made of wood, to render it impossible for any portion to escape coming into contact with the mercury. This part of the apparatus admits of being locked up, so that none of the gold can be abstracted without the knowledge of the party possessing the key. The machine requires only two men to work it; but it may also be driven by steam or water, and gives, when properly constructed and managed, very satisfactory results.

DISTILLATION OF THE MERCURY.—When the amalgam has been formed by any of the methods or machines above-described—in all of which the object kept in view is to place the particles of gold in the most favorable condition for coming into contact with the mercury, and combining with it—and when the fluid metallic mass has been washed, and the excess of uncombined mercury strained off, the last operation required in this method of treatment is the separation of the mercury which remains combined with the gold in the form of a semi-solid amalgam. This is performed by distillation at a high temperature, in a cast-iron vessel prepared expressly for that purpose. Different forms may be given to the apparatus, according to the scale on which the operation is conducted; but a very convenient one is that represented in Fig. 228, where A₁ is a cast-iron sphere or shell made in two parts, and capable of being joined together in the middle by a flange and screws. From the top of the upper hemisphere proceeds a bent iron pipe, D, which dips into water contained in the vessel, C—the whole forming a convenient iron retort. When used, the hemispheres are taken asunder; the amalgam is intro-

duced, and the two halves are again screwed together and well luted with some refractory substance. The retort is then placed on any convenient support over the fire, B, which may be of wood or coal; the heat is

Fig. 228.



gradually raised, and the sublimed mercury, which is conveyed away by the tube, D, is condensed and collected in C. Care must be taken to prevent the end of the pipe from dipping too deeply into the water; for if the temperature of the fire happens to fall, a vacuum is produced in the retort, which, if the pipe be too deep, will cause the water to rush up into the globe, and produce an explosion. The end of the pipe is therefore introduced just below the surface of the water, so that if a small portion of the water be drawn up into the pipe, that which remains in the condenser, C, immediately sinks beneath the level of the orifice, and all danger is averted.

When the distillation is concluded, which is known by the cessation of any further accumulation of quicksilver in the condenser, this distilled mercury is collected to be used for future amalgamations. The gold which remains in the retort, A, is now comparatively pure; but still contains a mixture of silver, copper, or other metals, in greater or less proportion, according to the sources or localities from which it has been procured. The separation of these, with a view to the obtaining of the gold in a state of absolute purity, will form the subject of the next department of this treatise.

In the meantime, it may be repeated that the amalgamating process is chiefly applied in the working of auriferous veins, or *gold-mining* properly so called, in contradistinction to the much more common method of extracting the gold from drift-beds or stream-mines, by the mere operation of washing. In the former case, the gold, generally in very minute particles, is mingled with various other minerals and rocks, as pyrites, zinc-blende, quartz, *et cetera*, and can only be extracted after the whole has been reduced by stamping, to a very small size—in which state, the gold, often so minute as to be invisible, would be almost entirely carried away by a stream of water. It is here therefore that amalgamation offers peculiar advantages, as the mercury seizes on the gold, however finely reduced, and none of the precious metal is lost—provided the precaution be taken not to pulverize or stamp the ore too fine, when about to be submitted to those preliminary washings which precede the amalgamation. On the contrary, when about to be brought into actual

contact with the mercury, the ore or *schlich* cannot be reduced too small; and hence the importance of actually pounding it, if possible, under the surface of the mercury.

From these considerations it will be readily seen that the process of amalgamation is not only applied with advantage in the working of auriferous veins or lodes, but that it may also be employed to procure a profitable return from the re-working of the tailings or refuse of the Australian or Californian gold-diggers. The Editor has little doubt that the greater part of the abandoned diggings, which have yielded a large return by mere washing, will, in course of time, be worked over again by amalgamation; and, indeed, this *gleaming process*, as it may be termed, has already been applied in many cases with highly satisfactory results. To give an idea of what may be done with poor ores, when system and skill are brought to bear, it may be sufficient to state the average produce obtained from the stamped ores at Schemnitz, in Hungary, in 1842—recollecting that these had to be broken from the solid lodes at depths extending to two hundred fathoms. The total quantity stamped in that year was above forty thousand tons, and the average of the useful metals extracted from fifty tons was: gold, three ounces; auriferous silver, derived from the separating processes, by buddles or tyes, *et cetera*, three pounds three-quarters; lead, similarly obtained, eight hundredweight one-third; the ratio of the gold to the other materials being in this case as one part to half a million. In the case of a particular mine, called Siglisberg, not producing lead with the stamped ores, the ratio of gold was only as one part to seven hundred and sixty thousand; of auriferous silver, one to twenty-four thousand. Now, it is interesting and instructive to compare with this economical extraction of minute quantities from poor ores by the process of amalgamation the produce of the manipulation by washing at the Siberian workings, where a common average of the sands worked to profit is half an ounce in one hundred hundredweight, or fully double the amount last mentioned, and yet even the poorer ores of Hungary yield a remunerative return by amalgamation. It follows, that by the same process many auriferous sands in Siberia, as well as in other countries, which are at present neglected, as being too poor for washing, might be advantageously worked.

Separation of Gold from Arsenical Pyrites.—Another illustration of the importance of scientific knowledge in the working of gold mines, is furnished by the recent application of PLATTNER's method for the separation of gold from arsenical pyrites, in consequence of which the mines of Reichenstein, in Silesia, which, as already stated, had been abandoned for more than five centuries, were reopened with advantage eight or ten years ago. This successful application of a purely scientific suggestion is due to the skill and enterprize of W. GUETTLER, of Reichenstein, to whom, in conjunction with Professor PLATTNER, the inventor, a council medal was awarded at the Great Exhibition of 1851, for a series of specimens illustrating the different stages of the process. The principal agents employed are chlorine and sulphide of hydrogen. The following account of this novel and ingenious process is given in the published re-

ports of the Jurors :—The ore at Reichenstein is an arsenical pyrites, containing about two hundred grains of gold in the ton. The ore is roasted in a reverberatory furnace, surmounted by a large condensing chamber, in which the arsenious acid is condensed as fast as it is volatilized. There then remains, on the floor of the furnace, oxide of iron mixed with a certain quantity of arsenic, together with the whole of the gold. This is placed in a vessel so arranged that a current of chlorine can be passed through it, by which the gold and iron are taken up, and afterwards separated from the residuum by the aid of a certain quantity of water, and the gold is afterwards precipitated from this solution by sulphide of hydrogen. To prevent the admixture of iron at this stage, a few drops of hydrochloric acid is added to the solution before the sulphide of hydrogen is introduced. The auriferous compound having been separated from the liquor, is washed and heated in an open porcelain crucible, to drive off the sulphur, after which the gold is reduced to the metallic state by fluxing it in the usual way.

This simple and ingenious method, which has made it worth while to reopen the Reichenstein mine, is equally applicable to the vast quantity of refuse accumulated near many other old works.

METALLURGICAL OPERATIONS.—*Fusion.*—

When the gold is received from the *gold-washer*, in the shape of gold-dust, or when it has been separated from its ores by amalgamation or otherwise, it has now to be subjected to a series of metallurgical operations to obtain it in a state of perfect purity. The first of these operations is that of fusion with borax, and casting the metal into ingots, by which it is obtained in a convenient form, and freed at the same time from earthy and other impurities. For this purpose, the gold dust from the washings, or the spongy gold obtained by amalgamation, is mixed with a little dried borax, and is introduced into a black-lead crucible, which has been previously heated in a common melting furnace. After the fusion of the metal, a slag, consisting of the grosser impurities, accumulates on the surface; this must be thickened by the addition of a little bone-ash, and then skimmed off. The metal is now cast into bars, by being poured into iron ingot-moulds, which should be previously warmed, and oiled, by wiping the internal surface with a piece of tow dipped in sweet oil. It is an old practice, now discarded by some metallurgists as useless, to add to the metal, when thoroughly melted in the crucible, a small quantity of corrosive sublimate; the contents are then well stirred, and, in consequence of the volatilization of the sublimate, effervescence takes place. That this is attended with no injurious effect seems to have been fully established by a long experience, and that it may even be productive of benefit is probable, by bringing to the surface any extraneous matter which might be detached from the interior of the crucible, and so permitting its removal along with the slag. The crucibles which have been used in a series of such operations, retain a portion of gold, which renders it important to preserve them, with a view to the subsequent extraction of the precious metal by smelting.

SMELTING OF GOLD ORES.—Although the readiest method of extracting the gold from rich alluvial sands

is by repeated washings, in the manner already described, and although in the treatment of quartz rock, iron pyrites, and other auriferous minerals, the method involving the tedious operations of pounding, washing, and amalgamation is usually adopted, yet, in the latter case, the same object may be accomplished by direct *smelting*—a term technically applied to a process, or series of processes, by which a metal is extracted, by the agency of fire, from the substances with which it may be combined or mixed in nature. It is well known that by this method iron is extracted from its ore in the blast furnace, and some years ago a Russian gentleman, named ANOSSOW, even proposed to smelt in this manner the auriferous sand of the Ural, alleging that a much larger quantity of gold could be so obtained than by the most skilfully conducted process of washing. His method consisted in smelting the sand with iron, the latter being employed simply as a vehicle to collect the gold, or to perform, in its melted state, the same part as mercury in the processes already described. When the gold was obtained in this state of combination, the mass was exposed to the action of sulphuric acid, by which the iron was dissolved and the gold remained in the insoluble residue. From some experiments which were made at the Museum of Practical Geology in London, it was found that, if it were advantageous on the score of economy, cast-iron might really be so applied; and that when it is melted with gold, an alloy seems to take place, from which the greater part, if not the whole of the gold may be extracted by again melting the alloy in contact with lead, which abstracts the gold. With regard to ANOSSOW's process, experiments were reported to have been made on the large scale, which had perfectly succeeded; but a strong proof of its want of success is the fact that it has never been practically adopted.

Of late years much has been said and written respecting the smelting of what has been called *gold quartz*, or, in other words, the extraction of the metal from the quartz in the furnace. The Editor, therefore, in proceeding to explain the common method of smelting, will assume, in the first place, that quartz or silica is the auriferous ore which it is proposed to subject to this operation. From the well-known infusibility of this substance, it is evident, that mere exposure to the strongest heat of a blast-furnace, without the addition of a flux, would be of no use; for, although the gold would be melted, it would remain in the quartz, and no separation of the precious metal would take place. Even supposing the quartz to be first reduced to powder, the gold is present in too small quantity to separate from the infusible mass, and sink to the bottom. It is therefore necessary to add some substance which, at a high temperature, shall combine with the quartz, and produce a fusible compound, in which case the gold, more especially if combined with some other heavy metal, will, in virtue of its high specific gravity, fall to the bottom of the vessel.

The best flux for silica is carbonate of soda, but this is too expensive to be employed on the large scale. Lime, therefore, aided by the addition of oxide of iron, is usually employed for this purpose. Lime alone, or lime and clay in certain proportions, will combine with

quartz at a high temperature, and produce a fusible slag. Oxide of iron alone will also suffice. When practicable, it is desirable to obtain the oxide of iron by roasting auriferous pyrites, such as that found in California or the Tyrol, for then the proportion of gold is increased by that contained in the pyrites. Whatever flux be employed, it is necessary, in the first place, to reduce the quartz to a comparatively fine state of division, otherwise a considerable loss of time and waste of fuel would be incurred in effecting the perfect combination required to ensure the complete separation of the gold. Even in smelting, therefore, the crushing or pulverizing process is not dispensed with. Assuming that lime and oxide of iron are the fluxes employed, and supposing the pulverized ore to have been partly concentrated by washing, these substances are mixed in about equal proportions, and raised to a white heat in a blast or reverberatory furnace. When oxide of iron is employed as the flux, the reverberatory furnace is to be preferred, because in the blast-furnace a considerable portion of the oxide would be reduced, and a corresponding quantity of metallic iron liberated, long before the mixture attained the degree of heat requisite for the combination of the silica with the oxide.

The product of the combination is a fusible *slag* or glassy substance, through which the gold, also in a melted state tends to sink to the bottom of the furnace. But the portion of this metal present even in a large quantity of ore is very small, compared with the bulk of the materials through which it is now diffused, it would be difficult to collect it *per se*, without very serious loss, in a crucible, and still more so in a furnace, whether reverberatory or blast. The operation is therefore materially assisted by adding another metal which shall combine with, and absorb, the whole of the gold, and from which the latter can afterwards be easily separated—some metal, in short, which shall serve the same purpose at a high heat, as mercury serves at the ordinary temperature. Of all metals, lead is found to be the best-adapted for this purpose, not only on account of its readily combining with the gold in a melted state, but also as offering peculiar facilities for its subsequent separation from that metal. Lead has, therefore, been uniformly employed in the processes hitherto generally adopted for smelting gold ores. The lead may be added to the mixture of ore and flux, either in the metallic state, or in one or other of its combinations, from which the metal may be set free. The materials most commonly employed to furnish the lead are litharge and galena—the former the protoxide, and the latter the native sulphide of that metal—although the rich slags obtained both from the smelting furnace and ore-hearth are also occasionally used. When litharge is chosen as the medium for the introduction of lead, it must be mixed with charcoal, small coal, or coke-dust, in order to determine the reduction of the necessary quantity of lead to the metallic state; but when galena is used, it is mixed with scrap-iron, for the purpose of combining with the sulphur, and setting the lead free. The lead-slag which comes from the ore-hearth or the reverberatory furnace, is generally the most convenient and least expensive

material, as it contains a considerable per-centage of lead, and is readily prepared for use by grinding it to powder under the edge-roll, and mixing it with charcoal or other carbonaceous matters. In this case, also, it is important to add some scrap-iron to combine with any sulphur which may be present in the slag. Whichever of these substances be employed, the lead evolved, under the conditions mentioned, percolates through the mass, and subsiding by virtue of its high specific gravity to the bottom of the furnace, carries along with it any particles of the precious metal it may meet with in its course. The lead is afterwards separated by *cupellation*—a process to be explained shortly.

Smelting with Iron Pyrites.—Instead of directly employing lead as the means of concentrating the gold ores, a method has been practised in Hungary, in which iron pyrites, generally itself containing a portion of gold, is used with economical effect for the same purpose. When this mineral is heated to a certain temperature without access of air, it loses exactly half of its sulphur, and becomes converted into a fusible sulphide of iron, such as is produced by bringing a roll of sulphur in contact with a bar of iron raised to a white heat. Let it be assumed, therefore, that the ore consists of a mixture of auriferous iron pyrites and quartz, and that this ore is mixed with the appropriate flux for the quartz, as already described, and exposed to the requisite heat,—in this case a slag will be formed, and the sulphide of iron will unite with the greater portion of the gold present, forming a heavy regulus, which will subside to the bottom. The stratum of sulphide of iron thus found beneath the surface of the slag and scoriae produced by the fusion of the earthy and siliceous gangue, is technically termed a *matt*. If this matt, containing the gold, be now roasted, or *oxidized by heating it with free access of air*, whereby it is deprived of a further portion of its sulphur, and the product be mixed with a fresh quantity of crude auriferous pyrites, and smelted again, a second matt will be obtained, which will contain the gold from the first and second charges of the auriferous ore. This process may be repeated a third, fourth, or any number of times, until the precious metal has been sufficiently concentrated in the substratum of sulphide of iron to admit of its profitable extraction. The last matt, containing the whole of the gold which has accumulated from the successive charges, and brought, therefore, to any required richness, is then fused with metallic lead, litharge, or with a mixture of galena and metallic iron. The gold is abandoned to the liberated lead, from the top of which the impoverished sulphide may be readily skimmed off.

By this process, the gold is obtained in a more concentrated form, or mixed with a smaller proportion of lead, than when the latter is used directly as the means of separating and collecting it from the smelted ore. Still as the lead must be used for its final separation from the ore in all cases—even when the gold has been concentrated by washing and amalgamation—the employment of the iron pyrites in the manner above-described is only attended with advantage when it constitutes part of the ore itself, or when it can be readily and cheaply procured in sufficient abundance. When

it forms a principal ingredient in the ore, it is manifestly highly advantageous, in point of economy, to employ it as a vehicle for the concentration of the precious metal, while it contributes at the same time to increase the amount of the product.

Patent Smelting Process.—Some years ago a patent was secured for another smelting process, invented by Mr. LONGMAID, which consists in separating the gold from the quartz or siliceous ore, by introducing plates of wrought-iron into the melted mass. The quartz is first crushed to a fine powder, and fluxed with a mixture of lime and oxide of iron, as usual. Into the fused mass thus obtained, plates of wrought-iron are from time to time introduced, and withdrawn when their surface is found to be coated with a film of gold. The plates are then plunged into a vessel of melted lead, which dissolves off the precious metal, and afterwards again put into the furnace. This process is constantly repeated till the whole of the gold is extracted from the ore, and it is said to be thus obtained both more economically, and in greater proportion, than by the usual process of washing and amalgamation; but the Editor is not aware that this method has yet been extensively practised.

CUPELLATION.—The next metallurgical operation is the extraction of the gold from the lead, and this has been performed from the most remote antiquity by a process termed *Cupellation*. This process, which is very simple in principle, is, at the same time, one of the most elegant chemical operations ever invented. It depends on the circumstance that when silver and gold are exposed in a state of fusion to the action of the air or oxygen, they neither give off perceptible vapors nor are sensibly oxidized—they remain, in short, unaffected; whereas, under similar circumstances, lead and almost all the other metals are oxidized with greater or less rapidity. There is also an important peculiarity connected with lead, which renders it the only metal, excepting bismuth, applicable to the process of cupellation. This peculiarity consists in the circumstance, that the white oxide of lead, known as litharge, is fusible at a bright red heat, and in this state liquefies and absorbs into its mass any other metallic oxide with which it may happen to be in contact, but which, without the influence of the oxide of lead, would remain unliquefied by the heat. For example, if the oxide of copper be present, this oxide, which is a fixed infusible substance at the temperature of a common furnace, is taken up by the melted oxide of lead; and if the latter can be separated from the gold and silver, the oxide of copper will be expelled along with it.

This separation may be effected by different methods, but particularly by means of bone-ash, which possesses the peculiar property of absorbing the melted litharge, even when mixed with a certain proportion of other oxides, whereas it remains impermeable to the unoxidizable metals. Hence, if a vessel be formed of pounded and compressed bone-ash, and into this vessel a compound be introduced consisting of a mixture of litharge or oxide of lead, oxide of copper, and native gold, which always contains a certain proportion of silver; and if this mixture be exposed to the powerful heat of a furnace, the whole will be reduced to a state

of fusion; the oxide of lead, in melting, will combine with and dissolve the oxide of copper, and both will be absorbed by the bone-ash, while the mixture of gold and silver will remain in the vessel, melted by the heat, but otherwise unaffected. Hence it follows that gold and silver, or a mixture of the two, may readily be deprived of copper or any other oxidizable metals by cupelling them with oxide of lead. For this purpose it is not necessary to employ the oxide itself in the first instance. When metallic lead is heated to a temperature above its melting point, it rapidly combines with the oxygen of the air, the product being in the first place yellow oxide of lead, which appears as a scum on the surface; and when the temperature is raised to about bright redness, this oxide is converted into litharge or the white fusible oxide, which immediately melts. Pure copper requires not less than sixteen or seventeen times its weight in lead to be absorbed in the manner above-mentioned.

A vessel of bone-ash, formed for this purpose, is termed a *cupel* or *test*; and in using such vessels for *assaying*, the absorptive power of the cupel is the only agency employed to separate the gold from the lead and other oxidizable metals, as will be explained afterwards. It is otherwise in cupellation on the large scale; in this case the cupel is soon saturated, and the greater part of the litharge is expelled by a different method.

The English method of cupellation or refining is as follows:—A piece of bar-iron, about half an inch thick and four inches deep, is bent into the form of an oval hoop, and the ends of the bar are welded together. The greater diameter of this hoop, which is destined to form the containing circumference of the cupel or test, may be about four feet, and its lesser two feet six inches; but the dimensions vary considerably according to circumstances. On the lower part of the hoop are fixed a series of four or five flat bars of iron, arranged parallel to each other in the direction of the short diameter. The first of these is placed about nine inches from one end of the oval, and the others at about equal distances between this bar and the other extremity. The hoop is then placed with the cross-bars downwards upon a solid floor, and a quantity of pounded and sifted bone-ash is beaten firmly into it with a mallet or rammer until it is entirely filled, or the bone-ash is level with the upper edge of the hoop. The bone-ash employed for this purpose is mixed with about one-tenth, by measure, of fern-ashes, or one-fortieth by weight, of American pearl-ashes, and moistened sufficiently to become coherent by pressure. The fern or pearl ash has the property of giving greater consistency to the bone-ash when heated. When the hoop or frame has been well filled with this mixture and solidly beaten down, the surface is carefully scooped out with a trowel all round the centre, so as to form a shallow concavity of about two inches and three-quarters in depth, leaving a wall of bone-ash all round, about two inches in thickness at top and three inches at bottom, except at one end, where a thickness of five inches is left; whilst the thickness of the sole itself is reduced to one inch above the upper surface of the iron cross-pieces. At that end of the test where the wall was left five inches thick,

and which is termed the *breast*, a segment of the bone-ash, contiguous to the hoop, is removed.

This apparatus is represented in Figs. 229 and 230, of which the former is a plan, and the second a longitudinal vertical section of the cupel or test. In these drawings, the letters A A denote the iron hoop; *a a*, the

Fig. 229.

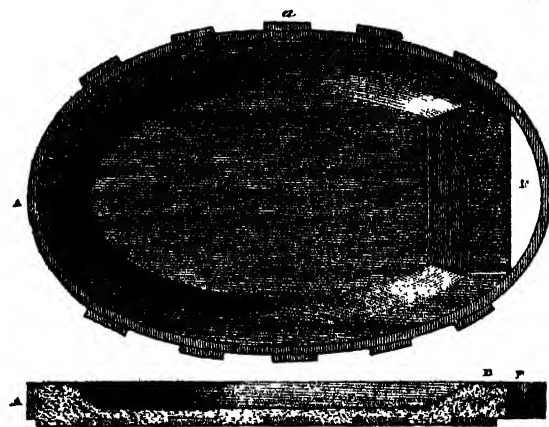


Fig. 230.

transverse bars; E indicates the cavity in the bone-ash; B, the breast; and F, the space where the bone-ash is removed between the breast and the iron.

When fully prepared, the test is allowed to dry, and is then placed in a furnace, constructed in all respects like a common reverberatory, except that a space is left open in the bed of the furnace to receive the test, and that the long axis of the arch is very short. The test, in fact, forms the bed of the furnace, in which it is adjusted with the long diameter transversely. It is supported in its place by an iron ring built into the masonry, or by iron bars placed underneath, between the two walls of the furnace. The fire-place of a cupelling furnace is usually about two feet in breadth, and two feet six inches in length. This is separated from the body or bed of the furnace by a fire-bridge eighteen inches in breadth, so as to allow the flame and heated air to pass directly over the surface of the cupel, from whence it escapes through separate flues into a high chimney. At the side of the furnace opposite to the breast of the cupel, the nozzle of a pair of large double bellows, or a fan-blast, is introduced.

When the cupel is inserted and the furnace lighted, the heat must be applied in the first place with much caution; for the cupel or test, if exposed suddenly to a high temperature before it has become sufficiently dry, is liable to split and fall to pieces. In the meantime, the lead containing the gold and silver, and which, from this circumstance, is termed *rich lead*, is brought to a state of fusion in a cast-iron pot, set in brickwork at the side of the furnace; and when the test has been cautiously raised to a cherry-red heat, the rich lead is laded into it till nearly full. Oxidation now proceeds rapidly. At first the lead becomes covered on the surface with a yellow or grayish dross; but on further raising the

heat, the surface of the bath uncovers, and a film of melted litharge begins to appear. Part of this litharge sinks into the bone-ash of the test, which it soon saturates. The blowing apparatus at the back of the test is now set in motion, and forces the litharge as it forms forward to the breast, B, across the surface of which a channel is cut, through which the litharge begins to flow, and runs over at the end through the vacant space, F, into a movable iron pot, placed on the floor for its reception. By this means the oxide of lead is prevented from coming in contact with the iron frame of the test, on which it would exert a powerfully-corroding action. The current of air introduced at the back of the cupel not only assists in clearing away the litharge, but readily supplies the amount of oxygen necessary for its rapid formation. In proportion as the litharge flows away, more of the melted lead is gradually supplied to the test, which is done by lading it into a channel from the pot outside the furnace.

After a certain period, the channel first formed in the breast, B, becomes much corroded; it must then be stopped, and a second and third channel successively formed for the same purpose. In this manner the operation may be continued until six or eight tons of the rich lead have been refined on the same test. Sometimes, however, two tests are employed, the first to concentrate the lead, and the second to separate it entirely from the precious metals. In this case, when the lead has been so far concentrated in the former that the whole of the gold and silver contained in the alloy may remain in combination with only two or three hundredweight of that metal, a hole is made through the bone-ash of which the bottom is composed, and the concentrated lead is received into a pot which is placed below. The tapping-hole is then closed with a pellet of moistened bone-ash, and a fresh charge of the original rich lead is concentrated in the same manner. When a sufficient amount of concentrated lead is thus accumulated to yield, as ascertained by assaying a small portion, from one to two thousand ounces of the precious metals, the whole is again melted down, and submitted to a second cupellation in another test, in which the operation of refining is completed.

Towards the conclusion of the operation some striking appearances are presented. As soon as the last portions of lead are removed, the liquid alloy of gold and silver in the cupel suddenly assumes a bright and resplendent surface; and, if the gold present is mixed with a considerable amount of silver, the surface of the mass, as it cools, is suddenly thrown into agitation; cones, or little craters, sometimes several inches in height, are thrown up, from which oxygen gas escapes with violence, projecting particles of silver with considerable force. This phenomenon is termed *spitting*, or sometimes *vegetation*, from the beautiful arborescent forms which are presented; and arises from the circumstance that metallic silver, when melted, has the property of temporarily combining with or absorbing much more than its own volume of oxygen, which escapes or is ejected with violence at the moment of solidification. For reasons especially connected with the final process of *parting*, and which will be afterwards explained, there

is almost always introduced into the alloy, before cupellation, a comparatively large amount of silver, so that the phenomena above described are almost uniformly observed at the conclusion of that process. Even in the cupel, the presence of a considerable proportion of silver is important, for the purpose of diluting the gold, and so diminishing the chance of loss.

After the cupelling, the test, with its cake of alloy of gold and silver, is withdrawn from the furnace; the metallic mass is removed and cleaned from external impurities; and the bone-ash, saturated with litharge, and any other oxide that may be present, is knocked out and preserved for subsequent treatment, as it contains not only a considerable quantity of lead in a state of oxide, but also a small proportion of silver.

On the Continent, the process of refining is conducted without the use of a cupel, properly so called. No bone-ash is employed. The test, if it may be termed so, is the bed of the furnace itself, which consists of a kind of marl, firmly beaten down into a circular cavity, sloping from the sides to the centre, and allowed to dry. The roof of the furnace, which consists of a flat dome of bricks, built in a strong circular hoop of bar-iron, is movable by means of a crane. Several tons of lead are introduced at once, and after the roof has been replaced, the blast is transmitted through one or more apertures in one side of the furnace; the whole mass of metal is then worked off continuously, without any addition, till the lead is entirely removed, and the alloy of gold and silver is left fine.

PARTING.—The final operation of separating the silver from the gold, is termed *parting*, and is generally performed in this country by means of nitric acid, which dissolves the silver, without attacking the gold. On the Continent, the same effect is produced with *hot sulphuric acid*. In assaying operations, nitric acid is always employed, and therefore the precautions necessary to be observed in this case will be fully explained in connection with the subject of *assaying*. In the meantime, the process with sulphuric acid, as practised on the Continent, will be first detailed.

1. *By Sulphuric Acid.*—It is only of late years that the use of sulphuric acid for this purpose has been generally introduced on the Continent, in consequence of its being now manufactured so much cheaper than nitric acid, which was formerly the only acid employed. The operation is performed in a very simple manner, and if any copper has been left in the alloy, it is separated along with the silver. It is true that the copper should be entirely expelled by the process of cupellation; but, as this process is practised on the Continent, a considerable amount of that metal often remains in the mixture; and its presence is by no means injurious, but is rather useful, in the subsequent operation of parting with sulphuric acid. It is true that if too much copper be present, a sulphate is produced, of which only a limited proportion will dissolve in the concentrated acid. The proportion of gold also must be less, as compared with the amount of the silver, than when nitric acid is used. Experience has shown that the alloy should not contain more than one-twentieth part of copper; and that the proportion of the gold to the silver should not exceed one-fifth; whereas, with nitric

acid, it is sufficient if the weight of the silver amount to about three times that of the gold.

When the silver is not already present in the required proportion, which is never the case with native gold, the requisite excess must be introduced; for, when the amount of gold exceeds the proportions above-stated, the particles of silver are so enveloped in that metal as to resist for a long time the action of the strongest nitric or sulphuric acid. In the process of assaying, the proportion of rather less than three parts of silver to one of gold is very closely adhered to, for reasons to be afterwards mentioned; but in operating on the large scale with sulphuric acid, the proportion of the gold to the silver may vary from one-fifth to one-tenth, without inconvenience; and DUMAS states that the operation may be conducted with profit when the ratio of the gold to the silver does not exceed 1 : 1000.

The alloy being prepared in the requisite proportions, which is generally done by introducing the excess of silver before cupellation, is melted in a crucible, and granulated by pouring it into cold water. For one part of the granulated alloy, three and a-half parts of concentrated sulphuric acid are taken, and the mixture is put into a platinum vessel, which is then introduced into the furnace. The vessel should not be more than two-thirds filled, to guard against the effects of effervescence, which might throw out part of the liquid. It is then covered with a platinum hood, provided with a beak or tube for conveying the gases and vapors into a condensing apparatus. The capacity of the platinum retorts varies, and there is usually an assortment of different sizes, for treating alloys of different qualities, without the necessity of mixing them. After two or three hours' boiling, varying the time according to the size of the retorts, the silver, and any copper that may be present, are completely dissolved.

On the first application of sulphuric acid to this purpose, the operation was performed in iron retorts. Vessels of platinum were afterwards introduced, as this was considered to be the only metal which could perfectly resist the action of hot and concentrated sulphuric acid. Afterwards, however, the enormous expense required for a complete assortment of platinum retorts, induced the attempt to return to the use of iron, and successful experiments were made by M. TOCCHI, which proved that iron retorts might be safely employed, though platinum is still in use in many establishments. It was found that the very concentration of the acid presented, of itself, an obstacle to the precipitation of the silver or copper by the iron; and, further, that the interior surface of the retort acquired a coating of silver, so that the iron and the liquid soon ceased to be in contact. This point has not been sufficiently studied; but the fact has been placed beyond doubt that the operation succeeds very well in iron vessels, and accordingly, in many refining establishments, no other are employed.

It cannot fail to be observed that, assuming the proportions above given, the quantity of sulphuric acid is much greater than would be strictly necessary to convert the silver and copper into sulphates. Supposing the alloy to be as poor as possible in gold, theory would

indicate the following quantities of acid as being sufficient for this purpose:—

	Parts.	would require	Parts.	155 sulphuric acid.
Copper	50		861	" "
Silver	949	" "	0	" "
Gold	1	" "	1016	" "
Alloy	1000	" "		

But as the amount of sulphuric acid employed is actually 3500 to 1000 of alloy, there is an excess of about 2500 of acid, intended to hold the sulphates, and especially the sulphate of copper, in solution.

When the silver and copper are completely dissolved, the retorts are withdrawn from the fire, and the solution is left to cool, that the gold may settle to the bottom. The liquid is then decanted; the gold, which remains in the vessel, is carefully washed, and the waters employed in this operation are added to the sulphate solution. Lastly, the purified gold is melted, and after being cast into ingots, is ready for commerce.

The acid liquor, containing the sulphates, is poured into a leaden boiler, containing water and copper shavings. Heat is applied, and the sulphate of silver is soon completely decomposed. The precipitated silver is collected, and submitted to repeated washings, always adding the water to the boiler, for use in the next operation. Lastly, the silver is dried in a small iron pan, and is then melted in a crucible, to be cast into ingots.

The acid solution, which now contains only sulphate of copper, is evaporated in lead boilers till it is fit to crystallize. It is then put into the crystallizing pans, and the mother waters are further evaporated, to obtain more crystals. This process is continued till the liquid becomes very concentrated, and consists almost entirely of sulphuric acid. In this state it is termed *black acid*, on account of its color, which is due, in great part, to organic matters, dust, and other impurities, which fall in it during the evaporation in the crystallizing pans. The black acids, purified by concentration, may either be employed to repeat the same operation, or turned to useful account in different manufacturing processes, which do not require that the sulphuric acid should be pure and highly concentrated.

2. *By Nitric Acid.*—The operation of parting is performed with nitric acid in much the same way; but all the details of the process with this acid will be minutely explained in connection with the subject of assaying, for which it is uniformly used.

3. *By fusion with Sulphur.*—Another method of separating the gold from the silver, which is sometimes practised with alloys containing but very little gold, is by fusing the granulated alloy with three-tenths of its weight of sulphur; this combines with the silver, and forms a liquid sulphide, in which the finely-divided gold remains suspended. A small quantity of litharge is then added, which gives rise to the formation of sulphurous acid and sulphide of lead, and again separates a portion of the silver, which then combines with the gold, forming an alloy richer in the latter metal. This alloy, by its greater gravity, sinks to the bottom of the crucible, and, after cooling, is separated by the hammer from the superincumbent mixture of sulphide of silver and lead. When this mixture, which is

termed *plachmal*, is fused with a small quantity of litharge, it yields silver, which for the most part still contains a little gold. The richer alloy which subsided to the bottom of the crucible, is treated repeatedly with sulphur in the same manner, till the proportion of gold is raised to one-fourth, after which the final separation of the silver is usually effected with nitric or sulphuric acid. It will be observed that this process is similar in principle to the method already described for concentrating auriferous pyrites.

4. *By fusion with Sulphide of Antimony.*—In this case, the alloy is mixed with two parts by weight of sulphide of antimony, and fused, with constant stirring, in a crucible, which should be previously glazed with borax. By this means sulphide of silver is formed, and the gold combines with the antimony, forming a lower stratum of alloy, which is afterwards separated from antimony by simple ignition in the air, or by fusion with nitre. If the amount of silver in the original alloy exceeds one-third, a proportional quantity of sulphur must be added in the crucible. The sulphide of silver forming the upper stratum retains a small portion of gold, to separate which it is again twice fused with sulphide of antimony, and this is again removed by ignition or fusion with nitre. The same operations are repeated on the whole amount of antimonide of gold thus obtained, and the antimony is finally removed either by fusing the antimonide alone, while air is blown upon it, or by fusion with three times its weight of nitre. Sometimes it is melted into a mass by heating it with three-fourths of its weight of borax, one-fourth of nitre, and one-fourth of glass.

5. *By Cementation.*—Another method, which is practised in America, consists in arranging the granulated alloy in alternate layers, with a mixture of two parts of brick-dust and one part of chloride of sodium in porous crucibles, which are exposed to a low red heat in a wood fire for a period varying from twenty-four to thirty-six hours. The aqueous vapor from the wood permeates the crucibles, and acts upon the salt in such a manner as to separate hydrochloric acid, which then forms chloride of silver with evolution of hydrogen. The chloride of silver, together with the chloride of sodium, sinks into the brick-dust, and the gold obtained after washing, contains not more than from one-tenth to one-eleventh of silver.

In this case, without the brick-dust, the conversion of the silver into chloride would be only superficial, because the chloride first formed would protect the inner portions of the alloy from the action of the hydrochloric acid. But when the alloy is enveloped in brick-dust, the chloride of sodium is partly decomposed by the silica, yielding silicate of soda and hydrochloric acid; the latter converts the silver into chloride, which then fuses with the rest of the chloride of sodium, and this, sinking into the brick-dust, leaves a new surface of alloy exposed to the action of the hydrochloric acid.

The reader will observe that the three methods last mentioned are all more or less imperfect in their results, and that for the complete separation of the silver, recourse must always be had to the action of sulphuric or nitric acid.

ALLOYS OF GOLD.—STANDARD GOLD.—By the preceding series of mechanical, metallurgical, and chemical operations, gold may be brought to a state of nearly absolute purity; but in this state it is too soft to be employed with advantage in the arts, or for the purposes of the coinage. Gold is therefore almost always alloyed with a greater or less proportion of some other metal, except when it is found in the shape of the finest gold leaf, which requires for its proper manufacture the highest possible purity, because, although it readily forms alloys with most of the other metals, its malleability is greatly impaired by their presence in even a very small proportion. With some metals this effect is very remarkable; even one two-thousandth part of antimony, bismuth, tin, or lead, will render the gold quite brittle. At the same time, as a natural consequence, its hardness and sonorousness are increased.

The only alloys of gold of any importance in the arts are those formed with silver and copper, which tend to increase its hardness and durability, and are used also by jewellers to give the gold different tints, according to the proportions employed. It singularly happens that these are the metals with which it is chiefly combined in the native state, although it is likewise found associated with iron, platinum, tellurium, and other metals.

Gold may be alloyed with silver in almost all proportions, and, by its combination with this metal, it becomes not only harder and more sonorous, but also more fusible. As the proportion of silver increases, the color quickly passes through pale greenish-yellow into white. The malleability of gold is less diminished by silver than by any other metal. The maximum of hardness is found in the alloy containing two parts of gold to one of silver. The *green gold* of the jewellers contains twenty-five per cent. of silver.

The most useful alloy of gold is that which is formed with copper, and this is the alloy which is used for coinage. The addition of copper renders gold redder, harder, and more fusible. The maximum of hardness is exhibited by an alloy of seven parts gold and one of copper. An alloy containing twenty-two parts of gold and one of copper has a density of 17·157. English standard gold contains 8·33 per cent. of copper, or one part of this metal to eleven parts of gold. In France, the standard gold contains ten per cent. of copper. Gold contracts in the act of solidifying from a state of fusion, and cannot, in consequence, be made to receive sharp impressions by casting it in moulds. Coins are, therefore, stamped with a die, and plate is either stamped or embossed, and afterwards chased and carved, if necessary, by cutting tools.

Valuation of Gold Alloys.—In this country the standard of the alloys of gold is calculated in fractions of unity expressed in carats. Perfectly pure gold is taken as unity, and this is assumed to consist of twenty-four fractional parts termed *carats*, each of which is divided into four imaginary grains, and these are again subdivided into quarters and eighths. The carat is, therefore, ultimately divided into thirty-two thirty-seconds; so that unity, or absolute fineness, represented by twenty-four of these carats, may be con-

sidered as made up of $24 \times 32 = 768$ thirty-seconds. On this system, an alloy of gold, according to its composition, is spoken of as being so many carats fine, or so many carats and thirty-seconds of a carat. It has been stated above that the standard alloy of the English gold coinage contains eleven parts of gold to one of copper, or, in other words, twenty-two parts of gold to two of copper; it is, therefore, said to be twenty-two carats fine. If the alloy contained twenty-three parts by weight in the twenty-four, it would be twenty-three carats fine, or one carat *better than standard*. If, on the other hand, it contained only twenty-one carats, it would be one carat *worse than standard*; if it contained 18·5 of pure gold, it would be said to be eighteen carats, and sixteen thirty-seconds. The report of the assayer is always given in relation to standard. Fine or pure gold would be twenty-four carats fine, that is, there would be no alloy.

In calculation it is easier to use decimal fractions than the clumsy empirical system of counting by carats; and in estimating silver the decimal method has lately been introduced into the mint of this country by Sir John Herschel. In France the same method is generally extended to gold. Upon the decimal system, fine gold or silver is termed 1000·0, and the report upon any sample of alloy simply indicates the number of parts of pure gold or silver in 1000 which the sample contains. Unfortunately the English standard does not admit of expressing the amount of copper in a terminable decimal, the nearest convenient fraction being 90·91 of copper in 1000 of alloy. In France, the standard is conveniently expressed by 900 of gold to 100 of copper. This decimal standard admits of the ready comparison of gold alloys with other chemical compounds, because in analytical investigations the results are always sought with reference to the percentage or centesimal composition of the subject under examination; but, under the system existing in this country and on many parts of the Continent, it is often necessary to convert the percentage into the corresponding value expressed in carats. The following table, which expresses the relation subsisting between a series of decimal fractions of unity and the carats and thirty-two thirty-seconds respectively, will be found convenient for immediately effecting the conversion:—

Thirty-seconds of the carat	Decimal.	Carats.	Decimal.
1	0·001302	1	0·041667
2	0·002604	2	0·083334
3	0·003906	3	0·125001
4	0·005208	4	0·166667
5	0·006510	5	0·208333
6	0·007912	6	0·250000
7	0·009215	7	0·291666
8	0·010415	8	0·333333
9	0·011718	9	0·374999
10	0·013021	10	0·416667
11	0·014323	11	0·458330
12	0·015625	12	0·500000
13	0·016927	13	0·541667
14	0·018230	14	0·583333
15	0·019531	15	0·624999
16	0·020833	16	0·666667
17	0·022135	17	0·708333
18	0·023438	18	0·750000
19	0·024740	19	0·791666
20	0·026042	20	0·833333
21	0·027344	21	0·874999
22	0·028646	22	0·916666

Thirty-seconds of the carat.	Decimal.	Carats.	Decimal.
23	0.029948	23	0.958333
24	0.031250	24	1.000000
25	0.032552	.....	.....
26	0.033854	.....	.....
27	0.035156	.....	.....
28	0.036460	.....	.....
29	0.037760	.....	.....
30	0.039062	.....	.....
31	0.040364	.....	.....
32	0.041667	.....	.....

JEWELLERS' GOLD.—The jeweller receives his gold in the form of ingots, which approach to absolute purity, or twenty-four carats fine. He begins his operations by alloying it with copper or silver, or both, in certain calculated proportions, either to reduce it to the legal standard, or to give it the particular color required. The following are the three standards fixed by the latest statutes enacted in France on the subject:—

1. *High standard gold*, consisting of nine hundred and twenty parts of pure gold in one thousand of alloy, which is equivalent to twenty-two carats, one thirty-second and one-half. This is the alloy usually employed by the French jewellers, and is nearly identical with the standard gold of the English coinage.
2. *French standard gold*, consisting of eight hundred and forty parts of gold in one thousand of alloy, or twenty carats, five thirty-seconds, and one-half. Sometimes it is reduced to only twenty carats.
3. *Common gold* is seven hundred and fifty parts in one thousand, or eighteen carats. The licence or *tolerance* allowed is three parts in a thousand.

In order that the gold may be easily worked, the alloy must be perfectly homogeneous, and the jeweller accordingly brings it to this state by repeated fusions. If the alloy has been badly made, and still exhibits a grainy appearance, with a liability to crack under the action of the hammer or between the laminating rollers, it must be again introduced into the crucible, and thoroughly fused with a mixture of borax and saltpetre.

In the *Dictionnaire des Arts et Manufactures*, the colors most commonly required in articles of jewellery, are stated to be composed as follows:—

Colors.	Composition
Yellow gold,	Pure or fine gold, 1000.
Red gold,	Fine gold, 750; rose copper, 250.
Green gold,	Fine gold, 750; silver, 250.
Dead-leaf gold,	Fine gold, 700; silver, 300.
Water-green gold, ...	Fine gold, 600; silver, 400.
White gold,	{ An alloy of gold and silver in which the latter predominates.
Blue gold,	
	Fine gold, 750; iron 250.

The last-mentioned alloy is somewhat difficult to prepare. It is obtained by introducing thick iron wire among the melted gold, and withdrawing the crucible from the fire as soon as the alloy is formed. When poured out and cooled, it should have no appearance of porosity. It is then forged, and formed into sheets or wires of different thicknesses.

Various shades of color are likewise given by the jeweller to articles or ornaments of gold, by the finishing process, which consists in exposing them to certain chemical agents, to dissolve out a portion of the copper or silver from the surface, without attacking the gold. By this means the surface of the article is made to appear like pure gold, which it really is, while below the

surface the quantity of copper or silver may be considerable. The liquor usually employed by the goldsmiths and jewellers for this purpose is a mixture of two parts of nitrate of soda, one part of chloride of sodium, and one of Roman alum, in three or four parts of water. The trinkets or other articles are kept in this solution, at the boiling point, from fifteen to twenty-five minutes, according to the shade required. They are then taken out, washed in water, and after burnishing with blood-stone, the operation is finished. The pickle, or sauce, as the liquor is termed, dissolves not only the copper or silver alloy on the surface, but likewise a certain quantity of the gold itself, and the articles lose, on the whole, about one-sixteenth of their weight by the operation. To recover the gold, the liquor is diluted with at least twice its bulk of boiling water, and a solution of very pure protosulphate of iron is poured into it. The precipitated gold is washed upon a filter, dried, and purified by fusing in a crucible, along with a mixture of equal parts of nitrate and bichloride of soda. The other metals can likewise be recovered by very simple methods.

GOLD-BEATING.—The art of beating gold into thin leaves seems to have been known from a very remote period. The fact that the Hebrews were acquainted with it has been already stated,—and from the circumstance that, on the coffins of the Theban mummies, specimens of leaf-gilding are met with, in which the gold is so thin as to resemble modern gilding, it may be inferred that the Egyptians had carried the art to a high degree of perfection. This art is distinctly referred to by HOMER, and was practised extensively by the later Greeks, even to decorate the external sculpture of their temples and statues. PLINY states that after the destruction of Carthage the Romans began to gild the ceilings of their temples and palaces, and that luxury advanced on them so rapidly that, in a little time, even private and comparatively poor persons gilded the walls, vaults, and other parts of their dwellings. HORACE's remark, that *neither ivory nor gilded arch figured in his house*, is familiar to the classical student. PLINY further states, that one ounce of gold was extended to 750 leaves, each four fingers square. LUCRETIVUS compared the Roman gold-leaf to a spider's web, and MARTIAL described it as little other than a vapor; yet, according to PLINY's account, it must have been three times the thickness of the ordinary leaf-gold of the present time.

Experiments have been made to ascertain to what degree of thinness gold and silver could be reduced: it was found that one grain of gold was spread to the extent of seventy-five square inches, and the same weight of silver to the still more extraordinary dimensions of ninety-eight square inches. Taking one cubic inch of gold at four thousand nine hundred grains, it will be found that the gold was the three hundred and sixty-seven thousand five hundredth part of an inch in thickness, or about one thousand two hundred times thinner than ordinary printing paper. Thus, if three hundred and sixty-seven thousand leaves of gold were placed on one another they would constitute a pile only an inch high, while the same number of leaves of paper would form a pile half the height of

the Monument of London. The same *weight* of silver, though extended over a much larger surface, was thickest, owing to the difference in its specific gravity. In practice, the gold leaf is never extended beyond the one-two hundred and ninety thousandth part of an inch in thickness.

The late, Dr. URE erroneously states, that the gold used in gold-beating ought to be of the finest standard. Alloy, he adds, hardens gold, and renders it less malleable; so that the fraudulent tradesman who should attempt to debase the gold would expose himself to much greater loss in the operation than he could derive of profit from the alloy. From this statement it might be inferred that nothing but fine or perfectly pure gold is used by the gold-beater, whereas, in point of fact, it is variously alloyed, according to the color required. Indeed, it is not uncommonly supposed, among the workmen employed in the business, that fine gold is incapable of being reduced to thin leaves; but this also is an error. It is simply objectionable for commercial purposes, on account of its greater cost, and also on account of the adhesion which takes place when one part of a leaf of fine gold touches another, thus causing a waste of labour, by the leaves being spoiled. For work, however, which is to be exposed to the weather, fine gold is the best, being more durable, and not liable to tarnish or change color.

A London gold-beater, Mr. E. S. MARSHALL, exhibited specimens of gold-leaf at the Great Exhibition of 1851, for which the prize medal was awarded to him. The specimens were twelve in number, and embraced a regular gradation in color from red to nearly white—namely, red, pale red, extra deep, deep, orange, lemon, deep pale, pale, pale pale, deep party, party, and fine gold. The deeper colors were alloyed with from twelve to sixteen grains of copper per ounce, but no silver, since any admixture of this metal with so large a quantity of copper would considerably impair the malleability of the alloy; the medium colors contained from twelve to twenty grains of silver, with from six to eight grains of copper, to the ounce; and, lastly, the paler leaves contained from two to not less than twenty pennyweights of silver to the ounce, but no copper, for the same reason that silver was omitted in the red or deep-colored golds.

The process of gold-beating is purely a mechanical operation, but involving as it does one of the most important applications of this precious metal, it will be necessary to give a short account of it. The first operation is the *casting of the metal into ingots*. For this purpose the gold, either pure or alloyed, according to the color desired, is melted in a crucible at a higher temperature than is simply necessary to fuse it, by which its malleability is improved. It is then poured into moulds previously heated and greased on the inside, and cast into flat oblong ingots, each about three-fourths of an inch wide, and weighing two ounces. The ingots, when taken from the moulds, are annealed in hot ashes, which cleanse them from grease and increase the malleability of the gold. When the ingot is cold, the French gold-beaters hammer it out to the thickness of one-sixth of an inch, and expose it at the same time to repeated annealings; but this operation,

termed the *forging*, is omitted by the English gold-beaters. The next process is the *lamination*, which consists in repeatedly passing the ingot between two rollers of polished steel, gradually brought closer together, until it is formed into a riband of one and a half inch in width, and ten feet in length, to the ounce. By this means the ingot is spread out to a surface of nine hundred and sixty square inches of the thickness of rather more than one-eight-hundredth of an inch. The next operation is the *beating*, for which purpose the riband of gold, after being annealed or softened in the fire, is carefully divided with compasses and cut up into pieces of the size of a square inch, each weighing about six grains; about one hundred and sixty of these are placed by means of wooden pliers between the leaves of a *cutch*, which formerly consisted of a packet of fine calf-skin vellum, but now it is usual to employ a tough paper manufactured in Franco. A case of strong parchment, open at both ends, is drawn over the cutch, and this is enclosed in a second similar case at right angles to the first, so as to cover the edges which the first had left exposed. The cutch is then beaten with a seventeen-pound hammer, upon a smooth block of black marble, supported on a strong bench, and surrounded on three sides by a wooden ledge, while the front is left open, and has a leathern apron attached to it, to preserve any fragments of gold that may fall out of the packet. The hammer is short-handled, and is wielded by the workman with one hand, while with the other he occasionally turns the packet over, to distribute the force equally. The elasticity of the packet causes the hammer to rebound, and lightens the labor of the operator. At intervals the packet is taken up, and bent or rolled between the hands, to overcome any slight adhesion between the leaves and the interposed paper or vellum; or it is taken to pieces to examine the state of the gold, and to shift the central leaves to the outside, and *vice versa*.

When the gold plates of one inch square are thus spread out into four-inch squares, or to nearly the size of the leaves of the cutch, which generally requires about twenty minutes' beating, the packet is opened, and each leaf of gold is taken out, and cut with a knife into four equal squares, thus increasing the one hundred and fifty pieces to six hundred of nearly the same size as at first. These are put between the leaves of another tool, called a *shoder*, made of *gold-beater's skin*. This substance is the cæcum of the ox, which is first doubled, then prepared with solutions of alum, isinglass, white of egg, &c. &c., and after being beaten between folds of paper to expel the grease, is finally pressed and dried. The shoder is enclosed in parchment and beaten as before, but with a smaller hammer, about nine or ten pounds weight, till the squares of gold are again extended to nearly the size of the skins. The shoder requires about two hours' beating for this purpose. During this period, the packet must be often folded, to render the gold as loose as possible between the membranes. As all the leaves do not spread quite equally, the shoder is beaten upon after the more expanded leaves have reached the edges, the effect of which is, that these come out of the edges in the shape

of dust, and this allows time for the smaller leaves to reach the full size of the shoder.

The packet is now opened, and the leaves of gold, being spread on a cushion, are again subdivided into fours, by means of two pieces of cane cut to very sharp edges, and fixed down cross-wise on a board. This rectangular cross being applied on each leaf, with slight pressure, divides it into four equal portions, and is preferable to a steel knife, to which the gold, in its now attenuated state, would be liable to adhere. The two thousand four-hundred squares thus formed are separated into three parcels of eight hundred each, and the squares of each parcel are placed in another shoder or mould composed of gold-beater's skin, enclosed in the parchment cases, and beaten as before. This is the last and most difficult stage of the process. The mould must be made of the finest skins, about five inches square; and on the fineness of the skin, and the judgment and dexterity of the workman, the perfection and thinness of the leaf of gold depend. A seven-pound hammer is now employed, and after two hours' beating, the gold is reduced to the one hundred and fifty thousandth of an inch in thickness, and begins to transmit the rays of light. When the gold is quite pure, or but slightly alloyed, it transmits the green rays, but in gold highly alloyed with silver, the pale violet rays are transmitted. After being hammered another two hours, the leaves acquire the tenuity of ordinary leaf-gold, and average from three to three and a half inches square. The three beatings and two quarterings expand the gold to an area about one hundred and ninety times greater than it had in the form of a riband, and one hundred square feet of it weigh only an ounce. It is true that an ounce might be hammered to cover an area of one hundred and sixty feet; but in this case the gold would be too much attenuated for common use, and the extra labor and care required would not be compensated by any corresponding advantage. After the last beating, the leaves are lifted one by one with a delicate pair of long pincers, made of white wood, and are spread out on a leathern cushion by blowing them flat with the mouth. Broken or blemished leaves are rejected; the good ones have the ragged edges cut off with a square frame of sharp cane, which reduces them all to a uniform size, and are then placed in a book, the leaves of which have been rubbed with red ochre, to prevent the gold from adhering. Each book is capable of holding twenty-five leaves, and in this form the gold-leaf is sold for gilding picture-frames and books, and for the various ornamental purposes to which it is applied in the arts.

In this country the art of gold-beating was long confined to London, where it has been carried to higher perfection than in any other part of the world; but, of late years, efforts have been made on the Continent, with the aid of English gold-beaters' skin, to emulate the beauty and fineness of the English product; and the art is now practised successfully in different large cities in England, as well as in Scotland and Ireland. Latterly, machinery has been applied to supersede the arduous manual labor of gold-beating with the hammer, and machines for this purpose were sent to the Great Exhibition from France and the United States.

There was also exhibited a specimen of leaf-gold, manufactured in London by means of steam machinery; and there is little doubt that the article, so manufactured, will ultimately supersede the product of manual labor.

GILDING.—This is the art of applying a superficial covering of gold to articles of wood, metal, *et cetera*, chiefly for the purpose of ornament, but sometimes also for utility, as when it is essential that the article should be preserved from tarnishing. Gilding is practised by various methods, the principal of which may be classified under the following heads, namely: 1. Mechanical gilding with gold-leaf for wood, leather, *et cetera*; 2. Chemical gilding, properly so called, which is practised on metallic substances, and includes wash-gilding, or gilding by amalgamation; gilding by immersion and various other processes; 3. Electro-gilding, commonly known as the electrotype.

1. *Mechanical Gilding*, or gilding on wood with gold-leaf, is of two kinds, distinguished as burnish-gilding and oil-gilding.

In *burnish-gilding*, the process may be exemplified as applied to a picture-frame. In this case the gilder receives from the joiner a bevelled moulding twelve feet in length, which he prepares for gilding by a number of preliminary coatings of size, mixed with different substances. He first gives it a priming of hot size and whiting, this mixture being laid on in a somewhat fluid state, and therefore termed *thin-white*. It is prepared by melting the size in an earthen pipkin, and stirring in the whiting in fine powder by small portions at a time. When this first coating is dry the surface is examined, and all holes and irregularities are filled up with a mixture of whiting and size, made of the consistence of putty, but containing no oil. The moulding then receives four or five layers of a mixture similar to the first, but of greater consistence, and therefore termed *thick-white*, allowing time between each layer for the work to dry. While each of these last coatings is still wet, the fine work of the moulding is kept open by means of chisels, gonges, and other tools for the purpose. Sometimes two thick-whites are laid on successively, without allowing the first to dry, and are then worked into the shape of the moulding by hard stones of the required form. The whiting is now from one-sixteenth to one-twelfth of an inch in thickness, and is trimmed to remove the unevenness at the edges, after which the entire surface of the moulding is smoothed with pumice-stone, formed to fit exactly into the various parts, which are slightly wetted to promote the smoothing effect. The final polish of the whiting is given with glass-paper.

The moulding is now ready to receive the gold-size, which consists of pipe-clay, red chalk, black lead, suet, and bullock's blood. Of this mixture, which is sold to the gilder in a tenacious mass, rather softer than butter, a portion is taken and melted with common clear thin size; and while still slightly warm, is laid on with a brush, and with great nicety of hand.

The next operation is the gilding, for which several tools are required,—a leathern cushion to receive the gold-leaf, a knife for cutting it into different sizes, and a little instrument, termed a *tip*, for laying the leaf on the moulding. This last instrument consists of two

pieces of card glued together, with the ends of a row of camel's hairs fastened between them, and projecting from one inch to one inch and a half. The gilder having moistened with water a few inches of the moulding about to be gilded, and having cut a leaf into stripes suited to the width of the part on which it is to be laid, touches one of these stripes with the tip, to the hairs of which it slightly adheres, and transfers it to the moistened part of the moulding. When the whole of the moulding has been thus covered, it is set aside to dry.

The next process is the burnishing, which is performed by rubbing briskly over the gold a piece of flint or agate. This greatly increases its brilliancy, and does not injure the gold-leaf on account of the foundation of gold-size and whitening which yields under the hand. The parts which are to be in *dead gold* or *matt*, are left unburnished, but over these parts a very thin, clear size is passed, and, when dry, the gold is carefully wiped with soft cotton wool. The work is completed by wetting the matt parts with a pencil dipped in clear finishing size. The moulding is then passed into the hands of the frame-maker, who cuts it up and forms it into a frame of the required size.

When the frame or other article to be gilt is somewhat richly ornamented, *oil-gilding* is used. In this case the moulding is first whitened as before, but is then made up to the required shape, and decorated with composition ornaments before the application of any further primings. In this state the gilder receives the frame, and his first operation is to wash it, in order to free it from oil or other impurities. He then gives it two or three coatings of thin-white, mixed with a little soft clay, and several additional coatings are given to the parts intended to be burnished. Two or three coats of a moderately strong size called *clear-size* are now spread over the whole, after which the *oil gold-size*, consisting of a mixture of boiled linseed-oil and ochre, is laid on smoothly with a brush. After six or eight hours, when the oil-size has been partially dried, the gold-leaf is applied as before, except that in this case no water is used, the oil serving the same purpose. For deep ornaments, the gold is pressed in with cotton-wool, and in this case the gilding has to be repeated to remove the irregular fractures known by the gilders as *spiders' legs*. The work, which has still a ragged appearance, is now carefully gone over and smoothed with a brush—superfluous gold being removed from some parts and worked into others. This operation is termed *skewing*. The parts to be burnished are then treated as before, and finally the frame, after being dusted, is sized with clear size, and yellowed on the outside.

Another application of gold-leaf is to book-gilding. When the book is bound in leather, the back and sides to be gilt are first covered with a coating of isinglass, or white of egg, dissolved in a large proportion of water, and termed *glair*. This is allowed to dry, and when the gold-leaf is about to be laid on, a woollen rag, slightly moistened with hog's lard or sweet oil, but so as to feel almost dry to the touch, is rubbed over the leather. This causes the adherence of the gold-leaf, which is laid on over the whole space intended to be covered by the figure, and is then imprinted with a hot brass

block, cut to the required design or letters. For this purpose a blocking-press is employed, and in the upper bed is a cavity containing a row of gas jets for keeping the block at the proper temperature. After the block has been brought down by means of a lever, the gold is readily brushed off from the parts which have not received the impression. Books bound in cloth are treated in the same manner, except that they do not receive the preliminary coating of *glair*, the place of which is supplied by a portion of the glue under the cloth being raised by the heated block. The edges of the leaves of books are gilded in the bookbinder's press by applying a solution of isinglass or white of egg, moistened with oil, and then laying on the gold-leaf, which is firmly pressed down and burnished with agate, blood-stone, or polished steel. Instead of isinglass or ovalbumen, the serum of bullock's blood is often employed.

2. *Chemical Gilding*.—When metallic surfaces are to be gilded, the gold is applied either in the state of an amalgam, which is termed *wash-gilding*, or is deposited by chemical affinity from its solution.

Water or *Wash gilding* consists in applying evenly an amalgam of gold to the metallic surface to be gilt, and then dissipating the mercury by heat so as to leave on the surface a film of pure gold. Ordinary brass answers very well for gilding on, but the alloy which is now generally preferred is a mixture of copper, nickel, and zinc, which may be so proportioned as nearly to resemble gold in color. To form the amalgam, a small quantity of gold, reduced to grains or thin plates, is heated in a crucible till it becomes faintly red, and then thrown into mercury, also previously heated till it has begun to emit visible vapor. The proportion of mercury to gold is generally as six or eight to one. The mercury is then stirred with an iron rod till all the gold is dissolved. The crucible is now removed from the fire, and the amalgam, when cold, is squeezed in a bag of chamois leather, for the purpose of straining off the superfluous mercury. The true amalgam which remains consists of about thirty-three of gold and fifty-seven of mercury in a hundred parts; it is a yellowish silvery mass, of the consistence of butter.

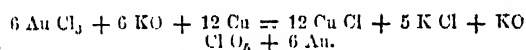
Before applying the amalgam to the metallic surface, the latter is rubbed over with a solution, formed by dissolving a hundred parts of mercury in a hundred and ten parts, by weight, of nitric acid, of specific gravity 1.33, and diluted with about twenty-five times its weight of distilled water. This solution not only cleanses the metal from any rust or tarnish, but in consequence of the stronger affinity of the copper alloy for nitric acid than the mercury has, the latter is precipitated upon its surface in the same manner as a piece of polished iron precipitates copper from a solution of the sulphate of that metal. The amalgam is now spread evenly over the alloy to be gilt by means of a brush, and readily adheres to the metallic surface in consequence of the thin film of mercury already deposited upon it. Sometimes the metal is previously cleaned with sulphuric acid, and the nitrate solution and amalgam are then applied simultaneously. For this purpose a gilder's scratch-brush, made with fine brass-wire, is first dipped into the nitrate of mercury solution, and is then drawn over a lump of amalgam, placed on

the sloping side of an earthen vessel, after which the brush is applied to the surface of the alloy. This process is repeated till the whole is coated with its just proportion of gold. The article is then bathed in water, dried, and exposed to a fire of glowing charcoal to expel the mercury. The heat applied must be just sufficient for this purpose, and the article must be turned about to expose it equally on all sides. From time to time it is withdrawn from the fire, and while the operator holds it in his left hand, protected by a stuffed glove, he spreads the amalgam equally with his right hand by means of a long-haired brush. The piece is then returned to the fire, and the same operations are repeated till the mercury has entirely volatilized. This is known by the surface becoming of a dull yellow color, and by the hissing sound of a drop of water let fall upon it.

The surface, now coated with a film of gold, is still deficient in polish and lustre. To communicate these qualities, it is washed and well rubbed with a scratch-brush in water acidulated with vinegar. It is then covered with a composition called *gilding wax*, which is simply a mixture of bees' wax with some of the following substances, namely, red ochre, verdigris, copper scales, alum, vitriol, and borax. Coated with this composition, it is again exposed to the fire until the wax is burnt off. By this means the gilding is found to be heightened in color, probably in consequence of the complete dissipation of some of the mercury remaining after the former operations. If the article is wrought or chased, the parts intended to be burnished are now rubbed with a steel burnisher, dipped in acidulated water, till a fine metallic lustre is produced. Formerly hæmatite or bloodstone was almost exclusively used for this purpose, but is now generally abandoned for the use of the steel burnisher, which is case-hardened and then carefully polished. The parts intended to be deadened are coated with a mixture of sea-salt, nitre, and alum, fused in the water of crystallization of the last-mentioned salt; the article is then heated till the saline crust with which it is covered enters into fusion, and becomes homogeneous, after which it is withdrawn and suddenly plunged into cold water, which entirely detaches the crust. Lastly, the piece is passed through weak nitric acid, washed in pure water, and dried.

Gilding by immersion is another method by which copper trinkets and stamped articles can be coated with a thin film of gold. This method, which dispenses with the dangerous use of mercury, so detrimental to the health of the workmen, was patented by Mr. ELKINGTON, of Birmingham, in 1836, and has been very extensively practised, more especially in France. In this process the copper or other metallic articles to be gilt, are, after being well cleansed, immersed in a boiling-hot solution of tetrachloride of gold mixed with a solution of bicarbonate of potassa. The adhesion of the gold to the inferior metal takes place in consequence of a portion of the copper becoming dissolved by the action of the potassa, and the deposition of an equivalent of gold upon the copper article in its stead. The details and rationale of the process are thus described by Dr. MILLER of London:—The gilding-bath is prepared by dissolving one part of fine gold in aqua regia,

and expelling the excess of acid by evaporation. The chloride is dissolved in a small quantity of water. To this solution thirty parts of bicarbonate of potassa are gradually added. This liquid is then mixed with a solution of thirty parts more of the bicarbonate, dissolved in two hundred parts of water, and the liquid is boiled for two hours. During this operation the bicarbonate of potassa is converted into the sesquicarbonate, and the yellow liquid passes into green; after this, the solution is ready for use. The trinkets having been annealed, are cleansed from adhering oxide by a momentary immersion in a mixture of equal parts of sulphuric and nitric acids; to which, when the gold is intended to have a *dead* appearance, a little chloride of sodium is added. The articles are washed in water, and then plunged into the gilding liquid, where they are left for about half a minute, after which they are washed in water and dried in hot sawdust. This bath may be also employed for gilding on German silver, platinum, or silver, by immersing the objects composed of these metals in the liquid, in contact with wires of copper or of zinc. During this process of gilding, a remarkable reaction occurs—the gold imparts a portion of its chlorine to the excess of potassa contained in the bath, forming chlorate of potassa; protochloride of gold is formed, and is decomposed by the copper,—chloride of copper being produced, whilst metallic gold is deposited upon the surface of the trinkets:—



During this operation a black powder is precipitated, which contains hydrated carbonate of copper, mixed with a small proportion of the purple of Cassius derived from the action of the gilding solution upon the tin contained in the solder of the trinkets. The compound termed the purple of Cassius will be described afterwards.

Gilding on iron and steel cannot be well performed directly by the method of amalgamation, as it is difficult to prevent the oxidation of the metal during the volatilization of the mercury, and the temper of sword-blades, daggers, and other such instruments, to which the gilding is usually applied, is liable to be injured in the process. It may be effected, indeed, by previously applying to the polished surface the solution of nitrate of mercury already described, and known as *quicksilver water*; the acid so applied unites with a portion of the iron or steel, and deposits in its place a thin coating of mercury, which combines with the gold amalgam when brushed on. By this method, however, a bright and durable gilding cannot be obtained.

Another not very successful method of gilding on polished iron and steel, is by means of an ethereal solution of tetrachloride of gold. For this purpose the gold is first dissolved in aqua regia, and about twice the quantity of ether is then cautiously added in a large vessel. The liquids are agitated and allowed to rest, when the ether will separate, and float on the surface of the acid. The whole mixture is now poured into a funnel terminating in a small aperture, and again allowed to settle and separate, after which the acid is run off from below. The ether which remains has taken up all the

gold, and before applying it to the iron or steel, the metal is polished with the finest emery and spirit of wine. The ether is then laid on with a small brush, and as it evaporates it deposits the gold, which can now be heated and polished. This gilding, however, is neither very rich nor durable, in consequence of the affinity between gold and iron being feeble compared to that between gold and copper or silver.

But polished iron and steel, as well as copper, may be effectively gilded with gold-leaf by the application of heat. For this purpose, the metals are heated till the iron assumes a bluish tint, and till the copper has acquired a like temperature. The first coat of leaf-gold is then applied, being pressed gently down with a burnisher, and then exposed to a moderate heat. Several leaves, either single or double, are thus successively applied, and the last is burnished down cold. This is the method usually practised in gilding iron or steel.

Gilding on silver is performed by means of the ashes of a linen rag, which has been dipped in a solution of gold and copper in aqua regia. For this purpose, sixty grains of fine gold and twelve of rose copper are dissolved in two ounces of aqua regia. With this solution a quantity of linen rags sufficient to absorb all the liquid is soaked. The rags are then dried and burned, and the ashes contain the gold in powder. A moistened cork or piece of leather is dipped into this powder, and after the article to be gilt has been well annealed and polished, the ashes are rubbed over it with the cork till the surface appears sufficiently gilded. Large articles are finally burnished with bloodstone, and small ones with steel burnishers, along with soap-water.

Gilding on glass or porcelain is effected with pulverulent gold, or gold precipitated from its chloride solution by means of sulphate of iron. In this state the gold is mixed with one-twelfth of its weight of oxide of bismuth, together with a small quantity of borax and gum-water, and is applied to the parts to be gilt with a camel's hair pencil. The article is then heated in a muffle, and when removed the gold appears of a dingy color, but the lustre is brought out by burnishing with agate or bloodstone. Lastly, it is cleaned with vinegar or white-lead.

Vessels which are not often used, and are not liable to wear, may easily be gilt in a less durable manner, by fixing gold-leaf upon them with copal varnish.

3. *Electro-Gilding*.—This process, which has now almost entirely superseded the method by amalgamation, is applicable not only to metals, but to wood, plaster, or any other substance capable of receiving a coating of plumbago, or of PARKES' patent preparation of phosphorus. Full details of this beautiful process have been given in the article ELECTRO-METALLURGY, to which the reader is referred.

ARTIFICIAL GOLD.—Under the name of Californian gold, and other sounding titles, are sometimes sold alloys which do not contain one grain of the precious metal, but merely resemble it in color and lustre so long as they remain untarnished. It is stated that a good imitation has lately been formed by Messrs. MOURIER and VALLENT, of Paris. The materials and

proportions used by them are—pure copper, 100 parts by weight; zinc, 17; magnesia, 6; sal ammoniac, 3.60; quicklime, 1.80; tartar, 9. The copper is melted in a crucible, in a suitable furnace; the magnesia, sal ammoniac, lime, and tartar, are then added, separately and by degrees, in the form of powder; the whole is stirred for about thirty minutes to thoroughly mix the ingredients, and the zinc is then thrown on the surface, having first been ground into very small grains; the stirring is continued until the fusion is complete. The crucible is now covered, and the fusion continued for about thirty-five minutes, when it is uncovered and skimmed with care, and the contents are run into a mould of moist sand or metal. The material which results may be cast at such a temperature that any ornamental form may be given to it. It is very fine-grained, and is also damascene, malleable, and capable of taking a very brilliant polish. When tarnished by oxidation, its brilliancy can be restored by a little acidulated water. If tin be employed instead of zinc, the alloy will be still more brilliant.

COMPOUNDS OF GOLD.—Apart from the alloys of gold, the only chemical compounds of this metal possessing any importance, are the chlorides, the oxides, and a substance known as the *purple of Cassius*, of which the composition is still somewhat obscure.

Chlorides of Gold.—Gold forms two compounds with chlorine,—a protochloride, AuCl , and a terchloride, AuCl_3 . The latter is the most important chemical compound of the metal, and from it nearly all the other useful preparations of gold are made. It is prepared directly by dissolving gold in nitro-hydrochloric acid. On evaporating the solution, the terchloride may be obtained in ruby-red prismatic crystals, which are very fusible, and deliquesce on exposure to the air. It is very easily decomposed by heat, light, organic substances, and all deoxidizing or reducing agents. Hence the fingers or writing paper, if washed over with the solution, become stained of a violet color when exposed to the sun's light; and hence also its occasional use in photography. It is soluble in water, in alcohol, and in ether; and the latter solution, as already stated, is sometimes used for gilding steel. When heated to about 350° , the terchloride is transformed, by the expulsion of two-thirds of the chlorine, into a pale-yellow sparingly soluble powder, which is the *protochloride*. This is an unstable compound of no importance in the arts. At a red heat it loses its chlorine entirely, and metallic gold remains.

The terchloride is the usual and most convenient form of obtaining a solution of gold, and examining its properties in that state. The different reagents by which pulverulent gold may be precipitated from this solution, have been already mentioned. It is by this means that gold is obtained in a state of chemical purity.

Oxides of Gold.—The oxides of gold correspond to the chlorides, and are obtained from them,—the protoxide, AuO , from the protochloride, and the teroxide, AuO_3 , from the terchloride. The *protoxide* is obtained as a dark green powder by precipitating the protochloride by a dilute cold solution of potassa. It is permanent at ordinary temperatures, but a heat bordering

upon 480° decomposes it into metal and oxygen; kept in contact with a solution of potassa for some time, it alters to metallic gold and the teroxide. When digested with ammonia, it forms fulminating gold. The *teroxide* which possesses acid properties, and is therefore frequently termed *auric acid*, is the only well-known oxide of gold; it is usually prepared by digesting a solution of the terechloride of gold with pure magnesia, washing the precipitate with water, and removing the excess of magnesia by dilute nitric acid; but WAGNER recommends the following process:—Dissolve one part of gold in the usual way, render it quite neutral by evaporation, and re-dissolve in twelve parts of water; add to the solution one part of carbonate of potassa dissolved in twice its weight of water, and digest at about 170° . Carbonic acid gradually escapes, and the hydrated teroxide subsides, of a brownish-red color. After being well washed, it is dissolved in colorless nitric acid of specific gravity 1.4, and the solution decomposed by admixture with water. The hydrated teroxide is thus obtained nearly pure, and is rendered anhydrous by a temperature of 212° . In the state of hydrate it is yellow, but when anhydrous it is nearly black. It is insoluble in water, is very readily reduced by solar light, and at a temperature of about 470° it is resolved into metallic gold and free oxygen. It is quickly dissolved in hydrochloric acid, yielding the common solution of gold; but although it is likewise taken up by strong nitric and sulphuric acids, it forms no true salts or definite compounds with these or with any acids containing oxygen: so slight is the affinity, that the oxide is quickly precipitated by the addition of water. The hydrated teroxide, however, readily combines with the alkalis, apparently forming regular salts, which are termed *aurates*.

FIGUIER gives the following method in preference to the above, in consequence of its yielding a larger product, and at the same time a *purer oxide*. Dissolve one part of gold in four of aqua regia, and evaporate to dryness on the sand-bath at a gentle heat; wash the dry residue with water, till the undecomposed terechloride of gold is removed, and add a further quantity of aqua-regia to the residue, which consists of metallic gold and protochloride; after solution, evaporate and wash as before, and repeat the process till the whole of the metal is obtained as neutral terechloride. Add the various liquors together, and then an excess of potassa, till there is a strongly alkaline reaction manifested on testing with turmeric paper. The menstruum becomes turbid, but before the teroxide of gold precipitates to any appreciable extent, chloride of barium is added. This causes the deposition of a canary-colored aurate of baryta. When the precipitate begins to present a whitish aspect, the addition of the chloride of barium is discontinued; the aurate is washed by decantation till sulphuric acid fails to show that baryta is contained in the washings, after which it is acted upon by dilute nitric acid, with the view of dissolving out the baryta. To effect the latter completely, it is necessary to raise the temperature to ebullition. As in the previous case, the nitrate of baryta is removed by decanting the liquor, and the several succeeding washings, till an acid reaction ceases to be discerned with blue litmus paper.

In drying the precipitate, care is necessary, since at 212° it partly decomposes. FIGUIER recommends the pressing of the matter between folds of bibulous paper, and subsequently exposing it in a dark situation to air, till the last traces of moisture are eliminated.

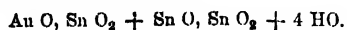
Any gold which may be carried off in the washings of the aurate of baryta, described above, is recovered by adding to them sulphate of iron, after their concentration and the removal of the baryta with sulphuric acid.

The washings and solution from the separated teroxide of gold may likewise be operated upon in a similar way, only that it is necessary to remove the nitric acid before doing so. For this purpose, the liquid is evaporated, and the residue boiled for some time with an excess of hydrochloric acid till nitrous acid ceases to be evolved.

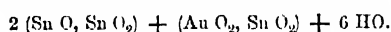
Fulminating gold may be prepared from recently precipitated teroxide, by keeping it in strong ammonia for about a day. A dark olive-brown compound is thus obtained. BERZELIUS assigns to it the composition $\text{Au O}_3 + 2 \text{NH}_3 + \text{HO}$, while DUMAS gives it as $\text{Au N} + \text{NH}_3 + 3 \text{HO}$. The Editor considers the former the more simple and probable view of its proximate composition, that is, regarding it as a diaurate of ammonia, and not a nitride of gold. A similar detonating compound is obtained when the terechloride is digested with an excess of ammonia; this is the ordinary mode of procuring fulminating gold. It subsides in the form of a yellow precipitate, the fulminating ingredient of which appears to be identical with that obtained from the teroxide. This compound may be dried at 212° ; but friction, or a heat suddenly raised to about 290° , produces a violent detonation. The best way is to dry it in the open air, and to make it only in small quantities at a time. Fulminating gold, however, has no application in the arts, in which respect it differs essentially from the following.

Purple of Cassius.—When a mixture of protochloride and bichloride of tin very much diluted, is added drop by drop to a dilute neutral solution of terechloride of gold, a flocculent purple deposit takes place, which has been termed *purple of Cassius*, from the circumstance that the method of preparing it was first described by ANDREAS CASSIUS of Leyden and his son, in 1685, under the name of *gold purple*. It may likewise be prepared by fusing together 150 parts of silver, 20 of gold, and 35.1 of tin, and acting on the alloy with nitric acid, which dissolves out the silver, and leaves a purple residue containing the tin and gold. To prevent the oxidation of the tin during the fusion, the three metals should be projected into a red-hot black-lead crucible, which contains a little melted borax. FUCHS states that the finest purple is produced by mixing a solution of sesquichloride of iron with aqueous protochloride of tin, till the yellow color is converted into pale green, and precipitating the gold solution with the mixture thus formed; he adds that the protochloride of iron in the liquid does not affect the product. This substance, in the moist state, is dark purple-red, and after drying, brown. Its true nature and composition have given rise to much discussion. According to some authorities, it contains metallic gold with hydrated stannic oxide;

according to others, the gold is oxidized. BERZELIUS concluded from the researches of M. FIGUIER, that it consists of a hydrated double stannate of gold and tin, as expressed by the formula,—



It is evident, as TURNER has remarked, both from the color of the compound, and its solubility in ammonia, that it is not a mechanical mixture of metallic gold and binoxide of tin, nor can it well be regarded as a chemical compound of these ingredients, since no definite combinations of that nature are known to chemists. The more probable supposition is, that it is a hydrated double salt, composed of binoxide of tin as the acid, united with protoxide of tin and binoxide of gold as bases, in such proportion that the oxygen of the gold exactly suffices to convert the protoxide into binoxide of tin. On this hypothesis, its composition would be expressed by the formula,—



Purple of Cassius is decomposed by the acids, but is not changed by the action of light. Hence it is somewhat extensively employed in the arts, chiefly for coloring glass and porcelain. When mixed with a little borax or some fusible glass, and applied to the surface of china, it imparts to it a beautiful rose or a rich purple color. Its different applications as a coloring material have already been explained in the articles ENAMELS and GLASS. It is remarkable that the oxide of tin does not appear to be essential, since even finely-divided metallic gold alone will give the same purple hue.

Burgos Lustre.—If finely-divided gold be heated with sulphur in contact with carbonate of potassa, a double sulphide of gold and potassium is formed, which resists a red heat, and is very soluble in water. This sulphur salt is likewise used for gilding porcelain, and produces the color known as *Burgos lustre*.

QUANTITATIVE ESTIMATION OF GOLD ORES AND ALLOYS.—In proceeding to determine the exact amount of gold present in an ore or alloy, it is obviously necessary to exercise the greatest caution in the sampling. Excellent advice on this point is given by Dr. PERCY in his admirable lecture on the metallurgical treatment and assaying of gold ores, delivered at the Museum of Practical Geology. Careless sampling, he remarks, can only mislead; assays of individual specimens may be accurate, but they are worse than useless if the assayer has not operated upon an *average* sample of the ore. He therefore advises the capitalist, to whom prospectuses of gold-mining schemes may be submitted, not to be allured with glittering specimens of gold ore, with assays yielding a high produce, and with the glowing statements of sanguine promoters or enthusiastic adventurers, without having ascertained on good evidence that the samples which are presented to his notice are really *average samples* of the ore, and that something like a continuous supply may reasonably be expected. If such specimens, he adds, do not represent an average, they become what the Cornish miner calls *stocking-stones*, which are at all times enticing and dangerous to the inexperienced and unwary, and never more

so than in the case of auriferous ores. The sampling generally devolves upon the miner, but the assayer and metallurgist should likewise understand the business. Assayers of great experience and high integrity may occasionally, he adds, commit unintentional mistakes. Thus, a few years ago, two small pigs of lead from South America, very rich in silver, were offered for sale. They were assayed by men of very high standing. Portions had been taken from the top and bottom of each pig, with a view to obtain a fair average. Dr. PERCY had occasion to attempt to verify the report of the assayers. Portions were taken from the same parts of each pig as in the first instance; but the results did not agree with the report, nor did Dr. PERCY's assays agree with each other on taking fresh portions. It was therefore certain that the composition was not uniform, and that the portions taken for the purpose of assaying in neither case represented an average. The pigs were accordingly sent again to the same assayers. Each pig was melted separately, and while melted a sample was taken. A second report was given, which differed from the former to the extent of one thousand ounces and upwards to the ton! In the sampling of gold ores most especial care should be taken, as the precious metal exists irregularly diffused through the mass, in particles of very different size, and as minute errors in sampling will necessarily be greatly multiplied when the quantity of gold per ton is calculated from the assaying of, it may be, five hundred or a thousand grains of ore.—*Percy.*

The quantitative estimation may be made, more or less correctly, by one of four methods: 1. By determining the specific gravity of the ore or alloy; 2. By the touchstone; 3. By chemical analysis, or the *wet method* of assaying; and 4. By the metallurgical, or *dry method*, in which fire is the principal agent. The first two afford only approximations, and the second is applicable only to alloys of gold; but both may be useful when circumstances render impossible or inconvenient the performance of an exact assay by the wet or dry method.

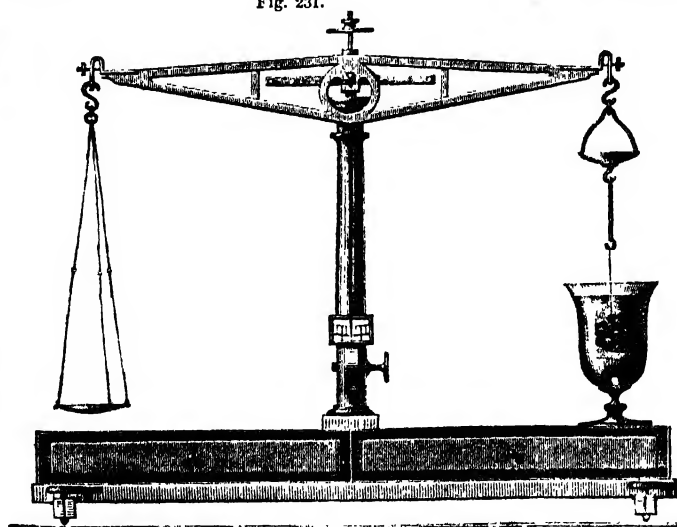
1. *Quantitative Estimation by Specific Gravity.*—It is evident that the high specific gravity of gold, in which it is exceeded only by platinum, not only affords facilities for separating it, by means of washing, from other matters, but also for estimating approximatively the amount in which it is present in any ore or mineral of known composition. The nature of the other ingredients being ascertained, and consequently their weight or specific gravity, the additional weight must be due to the presence of gold, and hence its amount may be calculated. Unfortunately, this quantitative test is rarely applicable to alloys, for experiment proves that an alloy composed of two metals has seldom a density corresponding to the mean which should be obtained by calculation from the relative amounts and specific gravities of its constituents. Thus, it has been found that alloys of gold with zinc, tin, bismuth, antimony, or cobalt, possess a greater specific gravity than the mean of the constituents, while alloys of the same metal with silver, iron, lead, copper, iridium, or nickel, have a specific gravity inferior to that of the mean. It will be seen that in the latter category are included the

metals most usually associated with gold, and hence it may be laid down as a general rule, that the specific gravity of *native gold*, containing an admixture of one or more of those metals, such as silver or copper, is *lower* than it ought to be theoretically. The following experiments by BOUSSINGAULT will show that a very remarkable discrepancy exists between the calculated and true specific gravity of a *native alloy* of gold and silver. In this case, three specimens of native gold were analysed, and their specific gravities, as found by experiment, are subjoined to the results obtained by a simple theoretical calculation:—

	First Specimen	Second Specimen	Third Specimen
Gold,	88.24	73.45	64.93
Silver,	11.76	26.55	35.07
	100.00	100.00	100.00
Calculated specific gravity,	18.22	16.93	16.17
Actual,	14.70	12.66	14.14
Difference,	3.52	4.27	2.03

It is evident, therefore, that an estimate formed from the actual specific gravities of these native alloys of gold, as found by experiment, would have given too low a figure for the amount of gold present. *It is remarkable, however, that these alloys acquire a higher specific gravity after being melted.* Thus, the specific gravity of the first specimen rose, after fusion, to 18.10, or very nearly to what it ought to have been by calculation. Hence it may be assumed, that in artificial alloys, a nearer approximation would be obtained to the true value by this method than with native alloys. At the same time, when, as in the case of Australian gold, the metal is nearly pure, it is evident that the amount of it present in a piece of auriferous quartz, may be deduced with considerable accuracy from its specific gravity, and as the same method is calculated to afford a useful and convenient approximation even in estimating alloys, the *modus operandi* will be explained.

Fig. 231.



Taking for granted, therefore, that the mineral proposed to be submitted to this test is a piece of auriferous quartz—the first point to be determined is its specific

gravity, or its weight as compared with that of an equal bulk of distilled water; because, if this be no higher than that of common quartz, which is found by experiment to average 2.6, it will be unnecessary to proceed further; but if higher, the amount of gold present may be calculated from the difference or excess. Now, the specific gravity of a solid insoluble body, such as quartz, is very readily found by the hydrostatic balance, which in its simplest form is a common pair of scales, with a horse-hair or fine thread attached to the under surface of one of the scale pans. This balance, in its most improved form, is represented in Fig. 231. The substance of which the specific gravity is required is weighed in air, and then, being attached to the hair or thread, is immersed in distilled water at the temperature of 60° Fahr. and again weighed. The difference of the two weights will be that of its own bulk of water, and the specific gravity of the substance is the quotient of its weight in air divided by this difference. This method of ascertaining the specific gravity of irregular solids was one of the great discoveries of ARCHIMEDES, and may be thus explained:—When a body is plunged beneath the surface of a liquid, it obviously displaces a bulk of such liquid equal to itself, and, consequently, it is pressed upward or supported in the liquid with a force exactly equal to that with which the particles of the liquid were supported, when they previously occupied its place; the solid will therefore appear to have lost weight exactly equivalent to that of the bulk or volume of liquid which it occupies. Supposing, therefore, the weight of the auriferous quartz in air to be W , and its weight in water W' , the difference, $W - W'$, will represent the weight of an equal bulk of water, and if S be the specific gravity of the auriferous quartz, or mixture of rock and metal:—

$$S = \frac{W}{W - W'}$$

Having thus obtained the weight and specific gravity of the compound, and knowing the specific gravity of the constituents, it is easy to calculate the amount or weight of gold present. Or, assuming G to represent the weight of the gold, and g the specific gravity of that metal; R the weight of rock or quartz, and r its specific gravity; W the weight of the compound in air, and W' its weight in water, as before; then the weight of gold in the specimen may be found directly by the following formula:—

$$G = g \left[\frac{W - r(W - W')}{g - r} \right];$$

and the weight of pure quartz, if required, by this formula:—

$$R = r \left[\frac{g(W - W') - W}{g - r} \right]$$

When the gold ore is in the state of powder or small grains, a somewhat different process must be employed to obtain the weight of a volume of water equal to that of the mineral under examination. In this case, the instrument called the specific gravity bottle, and repre-

sented in Fig. 232, is most conveniently employed. It usually consists of a cylindrical bottle, which may be

Fig. 232.



graduated or not, and the stopper of which, nicely fitted by grinding, is so adjusted that it cannot sink beyond a line marked upon the neck of the phial. When the latter is filled with distilled water, and the stopper inserted, the superfluous liquid escapes by a capillary tube which is formed in the stopper for that purpose, as shown in the figure, and thus the bottle is exactly filled, and all air is expelled. Such bottles are usually made to contain precisely one thousand grains of distilled water at the temperature of 60°, so that when once filled with water at that temperature, the weight of the included liquid is known.

To ascertain the specific gravity of an insoluble powder by this instrument, the powder is first weighed in the air by means of a delicate balance, and its weight noted. It is then introduced into the bottle of distilled water, from which, when the stopper is inserted, a portion of liquid will escape, precisely equal in volume to that of the mineral introduced. The bottle, containing the water and mineral, is now carefully wiped dry, and weighed—a counterpoise equal to the known weight of the bottle having been previously placed in one of the scales. The weight found will evidently be that of the whole water and mineral together, *minus* the weight of a volume of water equal to that of the mineral. If, therefore, *M* be assumed to represent the weight of the mineral in air, *W* the weight of water which exactly fills the bottle, and *W'* the weight of water and mineral in the bottle, it is evident that *M + W - W'* represents the weight of water which has been displaced by the mineral, or in other words, the weight of a volume of water equal to its own bulk. Hence the specific gravity, *S*, of the mineral, or its weight in air, in terms of an equal bulk of distilled water as unity, is found by this formula:—

$$S = \frac{M}{M + W - W'}$$

Suppose, for example, that the substance to be examined resembles gold dust, and that it is found to weigh in air 150 grains. Let the bottle be assumed to contain exactly 1000 grains of distilled water, and when a portion of this is displaced by introducing the heavier mineral, let the weight of the contents of the phial be 1140 grains. In this case, *M* = 150, *W* = 1000, and *W'* = 1140. Hence, *M + W - W'* = 10; and, consequently, by the preceding formula:—

$$S = \frac{150}{10} = 15$$

instead of 19.5, the specific gravity of pure gold; from which it may be inferred that a considerable amount of the precious metal is present, though very far from being in a state of purity. The absolute amount of gold can only be estimated, provided the nature of the substances with which it is associated is known.

The trouble of weighing the contents of the bottle

may be entirely avoided, and thus the operation simplified, by employing a modification of the same vessel provided with a narrow neck graduated to grains of distilled water, which will show at once the amount of liquid displaced. A phial of sufficient capacity to contain not more than from 150 to 200 grains of water, will generally be most convenient for this purpose.

2. Quantitative Estimation by the Touchstone.—Another method of estimating approximatively the amount of gold, not in auriferous ores, but in native gold or artificial alloys, is by the use of the touchstone—a method which may be practised with considerable advantage, when the apparatus and reagents necessary for the carrying out of a complete assay cannot be conveniently procured. It is more especially applicable to the estimation of trinkets or other finished articles, which could not be submitted to the assaying processes, either by the wet or dry method, without destroying them.

The touchstone test essentially consists in rubbing some convenient part of the object to be examined on a smooth piece of black basalt or pottery, which for this reason is termed the *touchstone*, and comparing the marks so formed with those produced by one or other of a series of small bars or needles, consisting of alloys of gold with silver or copper in known proportions. The material commonly employed as the touchstone, and generally known by that name, is a species of quartz, colored dark by bituminous matter, and of which large quantities are found in Saxony, Bohemia, and various other localities. Black flint slate will serve the same purpose. The sets of needles or bars may vary from pure gold, through a well-graduated proportion, to equal parts of gold and silver, equal parts of gold and copper, or various mixtures of all three metals in determinate quantities. The fineness of each bar is marked in carats—a mode of valuation which has been already explained.

In proceeding to make an assay by this method, the first streak obtained by rubbing the object to be examined on the touchstone cannot be safely employed to ascertain its composition, if it be a manufactured article, because, by a process previously described, the surface of jewellery is invariably rendered of a higher standard than that of the mass. The object must therefore be passed once or twice over the back or edge of the stone, in order to remove the superficial film of richer metal, before making the streak from which its quality is to be judged. Other streaks are then made successively with two or three of the needles which the assayer, guided by experience, considers to approach nearest in composition to the article under examination. In doing so, he compares not only the color of the streaks made upon the touchstone, but likewise the sensation of roughness, dryness, smoothness, or greasiness which the texture of the rubbed metals excites when abraded by the stone. When he succeeds in obtaining with one of his needles a streak which is perfectly similar in appearance to that produced by the article which forms the subject of experiment, he then moistens both streaks with nitric acid, which will affect them differently if they be not similar compositions. That which has the least gold will be

most affected; on the contrary, if the gold be pure, the streak will remain unaltered. If the actions do not correspond, his experience will enable him to judge in what they differ, and will direct him in selecting another needle to submit to the same comparative test. When one has been found which agrees satisfactorily in all particulars with the metal submitted to examination, the latter is assumed to possess a similar standard of fineness to that which is indicated by the mark on this particular needle.

Nitric acid of specific gravity 1.20 is commonly employed in this operation, with sometimes an addition of about two per cent. of hydrochloric acid. Although the results obtained cannot be relied on where absolute accuracy is required, yet they afford a useful approximation, not only in estimating the value of manufactured articles which cannot be submitted to a regular assaying process, but also in obtaining that preliminary knowledge of the general composition of an alloy, which is so important to the assayer in proceeding to a detailed analysis. The touchstone is therefore of great use in practised hands, but it is of little avail in the hands of an inexperienced operator.

3. Quantitative Estimation by the Wet Method—Analysis.—However useful the approximations obtained from the specific gravity of an auriferous ore, or the application of the touchstone to an alloy of gold, it is evident that more exact methods are required to determine with absolute precision the value of an alloy or ore of this precious metal. Accordingly, there are two methods by which the assaying of gold ores or alloys may be conducted with perfect accuracy, and these are distinguished as the *wet* or *dry* method, according as the agency of liquid solvents or that of fluxes and fire is employed. For practical purposes, in the determination of gold, the latter process is always adopted, although in the final separation of the silver even the dry method, as now practised, involves the application of a liquid solvent.

The principles of the quantitative estimation of gold by the humid method have been already explained in detailing the laboratory process for the preparation of pure gold, and in describing the application of the tests or reagents by which its presence is detected. It is evident that any of the qualitative tests which result in precipitating the gold from its solution in aqua regia, such as protosulphate of iron, may be converted into the means of obtaining a quantitative estimation, by simply weighing the amount of ore or alloy on which the experiment is performed, and then weighing the amount of pure gold, carefully washed and dried, which is obtained in the form of a precipitate. It will therefore be unnecessary to enter into minute details on the chemical principles involved.

It may be stated, however, that if the substance to be examined be a natural or artificial alloy, composed chiefly of the pure metal, such as the gold dust of California or Australia, the quantity taken for the analysis should not exceed fifteen grains. A convenient quantity is twelve and a half grains, as it is then only necessary to multiply the result by eight to obtain the per-centage composition. In performing analyses very small quantities are taken, because it is

easier to operate upon a few grains than upon a large mass; the effect of the reactions is more rapid; there is less waste of materials; and as accurate results can be obtained with a small as with a large quantity, provided sufficient precaution be taken to operate upon an average sample. If the gold be mixed with earthy or quartzose matter, so much of this should be taken as may be judged, from preliminary experiments or other sources of information, to contain the amount of native gold above-mentioned; and this must be triturated in a mortar with great care before subjecting it to the action of the aqua regia—a precaution of less importance in merely testing for gold, but absolutely necessary and essential when it is required to ascertain the exact amount of the precious metal present; for, unless the quartz be reduced to a state of the most minute division, it is evident that much of the gold remaining enveloped in the quartz will escape the action of the acid.

Whatever the precise amount taken, the ore or alloy to be examined must be weighed with extreme accuracy, and then introduced into a Florence flask or any other convenient glass vessel for boiling liquids. Supposing the compound to contain from twelve to fifteen grains of native gold, about an ounce of aqua regia is now poured upon it; the flask is then placed on a retort-stand or sand-bath, and the mixture is allowed to digest at a moderate heat for about half an hour. At the end of that time the gold will be completely dissolved, and the silver, if any be present, will be found in the form of an insoluble chloride, mixed with the silica at the bottom. The heat may then be increased under the flask, and the solution boiled off until it is diminished to about an eighth or tenth of its original quantity. At the same time a little hydrochloric acid should be added occasionally for the purpose of expelling or decomposing the nitric acid, the presence of which is injurious in the after part of the process. The addition of a little carbonate of soda will serve the same purpose. The reader will recollect that the function of the nitric acid is merely to liberate the chlorine, which is the real solvent of gold.

When the evaporation has been carried sufficiently far, three or four ounces of water should be added, after which the contents of the flask must be allowed to remain in perfect rest until the undissolved matter has completely subsided, and the supernatant fluid is quite clear. The latter is then to be carefully decanted or filtered off, and to the residue about an ounce of fresh water must be added, left to stand till clear, again decanted or filtered; and this operation repeated five or six times, always adding the later washings to the first portion of fluid. The solution of gold now obtained will be very dilute. Add to it, therefore, a few drops of hydrochloric acid, and then introduce the protosulphate of iron, which, when the liquid is well stirred, will speedily precipitate the whole of the gold in the form of a brown powder. If oxalic acid be used for the same purpose, the liquid ought to be boiled. When the whole of the precipitate appears to have settled to the bottom, a few drops of the clear supernatant liquid should be taken out on the end of a rod, placed upon a surface of clean white porcelain, and

tested with a drop of the solution of protochloride of tin. If no purple precipitate be formed, it is a proof that the whole of the gold has been thrown down. If a dark brown coloring, but still no subsidence, be produced, this will indicate the presence of platinum. If any precipitate be observed, more of the sulphate of iron or oxalic acid must be added to effect a complete precipitation of the gold contained in the solution.

When the pulverulent gold has entirely deposited, the liquid must be decanted or filtered off with the greatest precaution. Care must be taken that not the smallest particle of the gold powder is allowed to pass away with the liquid. A little hydrochloric acid, which must be quite free from any admixture of nitric acid, is then to be poured upon the precipitate. This will remove any iron or other metallic impurities without dissolving the gold. The latter is then to be washed, at least six times, with successive portions of distilled water; and lastly, it is transferred to a small porcelain or platinum crucible, in which it is heated over a spirit lamp, till the last portions of water are expelled. It ought, in fact, to be raised to a red heat, or even to be fused with a small quantity of borax and nitrate of soda, as formerly recommended, to expel the last traces of chloride of silver.

The pure gold thus obtained is then to be placed in a watch-glass or small capsule, and accurately weighed in a pair of delicate scales, which should be capable of turning with a difference of at least one-hundredth part of a grain. Instead of first counterpoising the dish or capsule, and then adding weights to counterpoise the gold, it is better to begin by placing the capsule containing the gold in one pan, and counterpoising both by means of sand, or some other convenient material placed in the other. The gold is then removed from the dish, and weights put in its stead sufficient to restore the equilibrium. The number of grains and fractions of a grain required for this purpose will accurately represent the weight of the gold; and in this method of weighing by substitution, as it is termed, any risk of error arising from the possible inequality in length of the two arms of the balance will be entirely avoided.

Supposing the gold to weigh exactly 10.75 grains, and that the amount of alloy submitted to experiment was 12.5 grains, or the eighth part of one hundred, it is evident that $10.75 \times 8 = 86$ is the per-centage of pure gold present.

4. Quantitative Estimation by the Dry Method—Assaying.—The fourth and last method of estimating the amount of gold in an ore or alloy, is by the use of fluxes and fire. It is therefore termed the *dry method*, and formerly even the separation of the silver was effected without a liquid solvent, by one or other of the dry processes described in connection with the operation of parting on the large scale; but now the agency of an acid solution is employed in the last part of the process.

This metallurgical method, to which the name of *assaying* is strictly confined, when not otherwise expressed, is that uniformly practised at the Mint, and other regular assaying establishments, being not only more expeditious than the wet method, but admitting

of a greater number of assays being conducted simultaneously. The wet method is useful for special or occasional assays in the laboratory, where assaying furnaces, cupels, *et cetera*, cannot be kept constantly in requisition. On the other hand, the dry method is the best where assaying is practised as a business, and where all the apparatus required is therefore in constant efficiency. This method consists in the following processes: 1. Fusion, to separate earthy and other gross impurities, which may be either performed in a crucible by means of oxide of lead, or by the method of *scorification* with metallic lead. 2. Cupellation, to remove the copper and other base metals by oxidation and absorption. 3. Parting by inquartation, or separation of the silver from the gold, by dissolving the former metal in nitric acid.

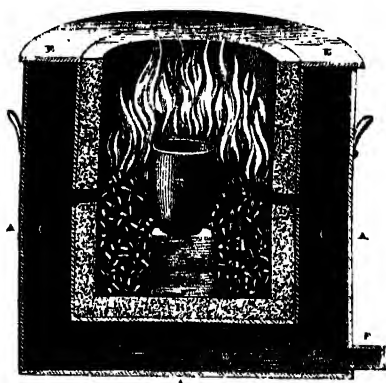
From this enumeration of the different operations which constitute the process of assaying by the dry method, it will be seen that this process is nothing more than a miniature representation of the smelting and refining operations already described. It will therefore be unnecessary to explain the principles on which this important department of the subject is founded, as those already enunciated in reference to the smelting and refining of gold ores, apply equally to the assaying of these ores, as well as of artificial alloys. The principal difference between the two cases consists in the fact, that the assayer operates upon a few grains instead of large quantities, while, at the same time, he must exercise the utmost precaution in attending to the weight and proportions of his materials.

Fusion with Oxide of Lead.—Assuming, as before, that the ore to be assayed is gold quartz, it must first, as in all other cases, be reduced to a fine powder, by triturating in an iron mortar. This operation is much facilitated by heating the quartz to redness, and plunging it in cold water. Having pulverized a few thousand grains, it is usual to make at least two assays of the sample, to test the correctness of the result. For each of these weigh five hundred or a thousand grains, according to the richness of the ore, and mix intimately on a clean surface of glass, or highly-glazed writing paper, with about the same weight of litharge or red lead, half the weight of dry carbonate of soda, and five per cent. of finely-powdered charcoal. The precise quantities are not very important; but it is better that the carbonate of soda should be in excess, than that it should fall short of the above proportion. This mixture is introduced into a Cornish or black-lead crucible, of which it should not fill more than two-thirds the capacity; it may then be covered with a thin layer of borax, and is afterwards fixed solidly in the assay-furnace, by surrounding it with fuel.

Furnaces proper for assaying are of several different kinds, and the required temperature may be obtained in them either by supplying an artificial blast of air by some blowing apparatus, or by connecting the furnace with a chimney sufficiently high to establish a strong natural draught. When the materials for its erection can be obtained, the ordinary wind-furnace is to be preferred. This is represented and fully described, in connection with the assaying of copper ores, at page 498, vol. I., to which the reader is referred. For the

travelling assayer, however, a portable apparatus is required, and in this respect SELFSTRÖM'S blast-furnace offers peculiar advantages. This consists of two cylinders of sheet-iron, placed one within the other, as represented in the annexed drawing, Fig. 233. A represents the outer cylinder, which answers the purpose perfectly well when not larger than a man's hat; and B the inner one, lined with a coating of fire-clay about an inch in thickness. Both cylinders are provided with a bottom, and are fixed together at the top, air-tight, by a horizontal hoop or flat ring of metal, E E, in such a way as to leave an equal space, C C, between their sides and bottoms. The interior cylinder, B B, is pierced at about the middle of its depth with eight holes, D D, which pass through the lining of fire-clay, and all point to the centre of the furnace, where the crucible, H, is placed on a piece of fire-brick, kept in

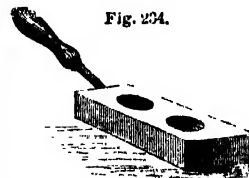
Fig. 233.



its position by a little fire-clay, and surrounded with fuel. For a small furnace of this kind charcoal must be employed as fuel, and should be broken into pieces about as large as a walnut. The air is blown into the opening, F, by means of a double-action bellows; or a simple rotating fan, like that employed for domestic fires, may be used. By this means the air is compressed into the space C, where it is partially heated, and is thence driven in a steady equable current through the holes D D, into the cavity of the furnace. The heat which may thus be produced with a furnace having an internal diameter of not more than six inches, is so intense as to be capable of melting manganese, or several ounces of cast-iron, with the greatest ease.

To proceed with the fusion. It has been stated that the mixture above-mentioned, when introduced into the crucible, should not fill more than two-thirds of its capacity. This precaution is necessary on account of the effervescence which will take place, owing to the displacement of the carbonic acid from the carbonate of soda by the silica, and the combination of the carbon with the oxygen of the litharge. The heat is continued till perfect fusion is effected, and towards the last the temperature is raised to bright redness, until no further effervescence occurs, and a clear liquid homogeneous slag is obtained. The crucible must then be immediately removed from the fire, otherwise the

unreduced litharge would be liable to cut through the pot; and as dexterously and rapidly as possible, the slag, which constitutes the upper portion of the contents, is poured into one of the two hemispherical cavities of a cast-iron ingot-mould, Fig. 234, and then the lead, with adhering slag, into the other. If any particles of lead are found attached to the slag which is poured into the first cavity, they must be carefully separated by trituration and washing, and added to the button of lead in the other cavity. The latter is then taken out, and struck carefully on the side, on a bright anvil, with a hammer, to detach any portions of slag that may still adhere to it. Sometimes the crucible is broken to extract the button of lead, but this may be avoided by the method above described, if executed with sufficient dexterity. The whole of the gold, with any silver that may be present, remains in the lead, which is then subjected to the process of cupellation.



The proportion of oxide of lead to be used in the fusion will necessarily vary with the amount of oxidisable substances present; but this compound should in all cases be added in excess, since, if the slags retain any traces of an alkaline sulphide, these will retain a part of the gold. PHILLIPS states that for the assay of iron pyrites about thirty parts of oxide of lead are necessary, whilst for mispickel, zinc blende, copper pyrites, grey cobalt, and sulphide of antimony, from fifteen to twenty-five times their weight only may be employed. When auriferous pyrites is the subject of examination, it must first be reduced to fine powder, and then roasted in a shallow dish of refractory clay, heated to low redness in a large muffle, until the odor of burning sulphur ceases to be evolved. As the sulphur burns away, the temperature is gradually raised to bright redness. The pyrites is thus converted into oxide of iron. Of this product one thousand grains or more may be taken, and mixed with five hundred of dry carbonate of soda, three hundred to five hundred of litharge or red lead, with five per cent. of charcoal, or the same quantity of granulated metallic lead without charcoal, and lastly, about five hundred of dried borax. This mixture is heated, introduced into the crucible, and fused as for quartz or other common ores. The fuel should be either charcoal, coke, or anthracite. For small portable furnaces, such as SELFSTRÖM'S, charcoal is employed, but anthracite is found to be well adapted for the air-furnace, and is characterised by the power of producing an intense heat in a short time, over a space confined to a few inches above the bars.

The principal objection to this method of assay is the large amount of lead which is produced for cupellation, since pure iron pyrites affords, when thus treated, eight and a half parts of lead, whilst sulphate of antimony and grey copper ore yield from six to seven parts. This inconvenience, as well as the trouble of roasting, may be avoided by the cautious and gradual addition of nitrate of potassa, which effects the partial oxidation of the mineral, and enables the skilful assayer to pro-

cure a metallic button of almost any required weight. The nitre, however, if employed in excess, would determine the oxidation of all the metallic and combustible substances contained in the mineral, except the gold alone, which is never present in sufficient quantity to form a button. The exact amount of nitre to be added must depend on the nature and richness of the ore. As a general rule, it may be stated that two and a half parts of nitre are sufficient to completely oxidise one part of iron pyrites, and that one and a half and two-thirds their weight, in the case of sulphide of antimony and galena, are sufficient to produce the same effect on these ores.

Alloys of gold containing *tin* and *zinc* must likewise be fused, before cupellation, with nitrate of potassa, to oxidise these metals; and by adding about sixteen parts of lead, when the mixture is quite melted, they are separated in the state of slag or scoria, leaving, as before, a button of lead containing the whole of the gold, which is now ready for being cupelled. But before describing this part of the assaying process, the method by scorification, which is often preferred to that of fusion with oxide of lead, will be briefly explained.

Method by Scorification.—Scorification, or, in other words, the conversion of the silica and other impurities into a scoria, is simply another method of fusion, in which, however, metallic lead, instead of its oxides, is employed; and the oxidation of the various substances to be removed is produced by the aid of atmospheric air, whilst the litharge necessary for the fusion of the earthy and silicious matters is formed by the oxidation of a portion of the metallic lead. For this operation, instead of a crucible, a shallow cup-like vessel, termed a *scorifier*, is employed. This vessel, the form of which

Fig. 235.



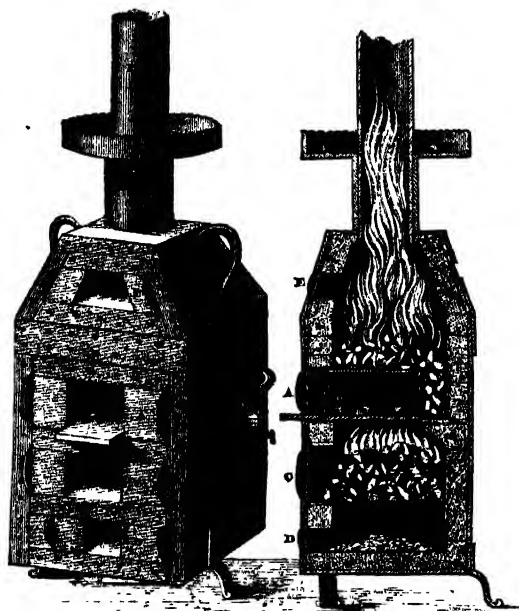
is represented in Fig. 235, should be made of refractory clay, and be as compact in structure as possible, in order to resist the corrosive action of melted litharge. The scorifier with its contents is heated in the muffle of an ordinary assaying-furnace, and as many assays may be introduced at one time as there is room for in the muffle.

A very convenient furnace for this purpose, as well as for the subsequent process of cupellation, is shown in elevation and vertical section in Figs. 236 and 237, and the form of the muffle is represented in Fig. 238. This last apparatus is a small arched vessel of fire-clay, closed at one end, and furnished with small holes or perpendicular slits in the sides and closed extremity, to allow of the free circulation of air through the interior. It is introduced by the opening, A, into the furnace, which is made of sheet-iron lined with fire-clay; and when adjusted in its place—as shown in Fig. 237—it is supported at one end by a shelf at the back of the furnace, while the other or open extremity exactly fits the opening, A, to the sides of which it is carefully luted by a little moistened fire-clay. In this position it is surrounded with ignited fuel, by which it is equally and readily heated on all sides; while the openings in its end and sides admit of the passage of a current of air into its interior, and the draught is kept

up by the addition of a long chimney or funnel, F, so that the muffle is constantly traversed by a highly oxidising current. The ledge around the chimney is

Fig. 236.

Fig. 237.



intended for drying the scorifiers or cupels before introducing them into the muffle. In lighting the furnace, a little ignited charcoal is first introduced by the opening, C, and the body of the furnace above and below

Fig. 238.



the muffle is afterwards well charged with the same fuel, or with good hard coke broken into small pieces. The whole of the openings are then closed by means of their slides or lids, with the exception of the ashpit, D, which is left open to supply the requisite draught.

Before introducing the ore into the scorifiers, it is reduced to powder, and a determined weight of it is intimately mixed with several times its weight of finely-granulated lead, free from silver. The scorifiers charged with this mixture are then placed in the muffle, and the door at the mouth being closed, they are strongly heated in the muffle during a quarter of an hour. By this time the lead will be completely melted, and the mouth of the muffle is again opened. The scorifying process now proceeds in consequence of the current of heated air which passes through the muffle; in other words, the lead is oxidised, and the foreign metals present, whether in combination

with sulphur or oxygen, are attacked and dissolved in the litharge in proportion as this oxide is formed. At first the slags are frequently solid, but gradually become soft, and more and more liquid in proportion as the quantity of oxide of lead increases. Towards the conclusion of the operation, the muffle is for a short time strongly heated to render the slag or scoria completely liquid. When a small iron rod, previously heated to redness and then placed in the mixture, is found, on being withdrawn, covered with a slight film of scoria which runs clean off, the scorification is known to be sufficiently advanced. The scorifiers are then successively withdrawn from the muffle by means of tongs, and the contents are rapidly poured into a circular ingot-mould of the form represented in Fig. 234. When cold, the adherent litharge is detached from the button of lead by a few blows with a hammer. This button contains all the gold and silver which may have been present in the ore, and which are subsequently separated from the lead by cupellation.

If the ore is poor, the whole of the precious metals contained in a large quantity may be concentrated in one small button of lead, by repeating the process on a fresh portion of ore mixed with a suitable quantity of lead, and introducing into this assay the button first obtained. A second button of the same weight as the first, and containing all the precious metals from the two quantities of ore, will thus be procured. The same process may be repeated a third, fourth, or any number of times, till the button of lead last obtained becomes as rich in the precious metals as may be required. It is necessary, however, that a certain amount of lead should be present, with a view to the next process, that of cupellation. In many cases so much as eight times the weight of the ore is employed, but the button may be reduced by a single operation to one-sixth or even to one-eighth of the original lead. Indeed, it is the highest recommendation of this process, as compared with the method by fusion with litharge, that however small may be the proportion of lead, the slags produced never contain any oxy-sulphides at the close of the operation, and, therefore, they seldom retain the slightest trace of either gold or silver. The process of scorification has therefore been justly characterized as one of the most exact methods that can be employed—simple, effective, and applicable to the assay of all kinds of auriferous and argentiferous ores, without exception.

Cupellation of the Assay.—The process of cupellation on the large scale has been already described. When applied to assays the principle is the same; but in this case the whole of the melted litharge and other oxidised matters are removed by absorption into the cupel; whereas it has been shown that, in operating on large quantities, the cupel is soon saturated, and the greater part of the litharge and other oxides are allowed to run away, or are expelled by the current of air which exerts the oxidising action.

The cupels for assaying purposes are formed of the same material as those employed for refining on the large scale, and described at page 284; but they are necessarily much smaller, and are considerably simpler in the manufacture. They are made by pressing the

moistened bone-earth into a mould, which consists of a short, stout cylinder, A—Fig. 239—either of cast-iron or gun-metal, open at both ends, and having the diameter of the cavity somewhat greater at the top than the bottom. Its usual dimensions are as follow:—Interior diameter at top, one and nine-sixteenths of an inch; interior diameter at bottom, one inch and a half; depth, two inches. To make a cupel, the cavity is nearly filled with bone-ash, which is first compressed slightly with the hands, and afterwards by means of the plunger, B, which is formed of the same metal as the mould, and has the lower end turned convex, so as exactly to correspond to the concave surface of the cupel. When the plunger is introduced, it is struck several times with a mallet till the bone-ash is well consolidated. The plunger is then withdrawn, and by inserting at the lower and smaller end of the mould a solid wooden cylinder, which exactly fits the aperture, the cupel is readily forced out, and is then placed to dry on the ledge which surrounds the furnace chimney—Figs. 236 and 237. The diameter of the cupel—Figs. 240 and 241—is about one inch and a half, and its cup-like cavity is very shallow, being not more than three-fourths of an inch deep.

Cupellation, like the process last described, is performed by means of a muffle, Fig. 238. When the muffle has become red-hot, six or eight cupels are successively introduced into it, by a pair of light tongs of the form represented in Fig. 242; and to prevent the

Fig. 239.



Fig. 240.



Fig. 241.

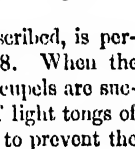


Fig. 242.



floor of the muffle being corroded should any of the oxide of lead be spilt on it, it is previously covered with a thin layer of pounded bone-ash. In the furnace of the Mint, the number of assays that can be made at one time is forty-five, and the same number of cupels are put into the muffle. When the cupels are introduced, the door of the opening into the muffle is closed for a few moments, while the draught-hole of the furnace is kept open till the cupels are raised to the temperature of the muffle itself. The slide is then withdrawn, and into each of the cupels is introduced, by a pair of slender tongs, a button of the alloy to be assayed.

By the previous process of fusion with litharge, or that of scorification, if deemed preferable, the earthy impurities have been removed in the form of slag or scoria, and nothing now remains but the gold, or a mixture of gold and silver, in combination with the lead and any other metals that may be present. The process of cupellation, as previously stated, consists in the oxidation of the lead and other oxidizable metals, and their absorption by the cupel. It is, in fact, a condition essential to the success of the assaying pro-

cess that the whole of the oxides should be imbibed, and thus removed. But the power of absorption in a cupel varies according to its texture, and the care with which the material has been prepared. On an average, it may be calculated that it will absorb about its own weight of fused litharge. This, though not strictly correct, will afford a general guide to the experimenter, as regards the amount of lead which ought to be mixed with the assay. It is evident, on the one hand, that this must not exceed the absorptive power of the cupel. On the other hand, the actual amount, within this limit, must depend on the nature of the compound or alloy upon which the cupellation is to be performed; but supposing that the subject of assay is an alloy of gold and copper, the following table will give the quantity of lead required for the separation of the copper. In treating an alloy of gold and silver with copper, the quantity of lead may be somewhat diminished; but, in cupelling an alloy of copper with gold alone, a small excess of lead is not injurious, as, in consequence of the gold not being volatile, like silver, the heat can be raised and sustained for any required length of time, so as to oxidize the last portions of lead. In this table, which is adapted by Mr. T. W. KEATES, from one given by BERTHIER for the assay of silver—the proportion of lead being altered to render it applicable to the cupellation of gold—the first two columns express respectively the quantities of gold and of copper, and the third column the parts of lead by weight required for one part of the alloy, according to its composition:—

Alloy		Proportion of lead required
Quantity of gold	Quantity of copper.	
1000	0	3-10 lbs
900	50	6
900	100	14
800	200	20
700	300	24
600	400	28
500	500	32 to 35
400	600	32 to 35
300	700	32 to 35
200	800	32 to 35
100	900	32 to 35
0	1000	32 to 35

It must be observed that the numbers in the third column indicate multiples of one part of the alloy. It may appear surprising that, at and below the point at which the alloy contains equal parts of gold and copper, the same proportion of lead is required, whatever may be the proportion of the copper. This fact, however, has been fully verified by experience. It requires, in short, as much lead to remove the copper from an alloy of equal parts of that metal and gold as it would to carry off a quantity of copper equal to the weight of the copper and gold together. It may be added, that when the assayer has reason to know pretty nearly the composition of the alloy, it is well to insure the presence of at least two or three times more silver than gold, which is not only useful in the cupellation, to guard against loss of gold, but is necessary, as already stated, for the subsequent operation of parting.

The assays being placed in the cupels, the door is a second time closed during a few minutes, to facili-

tate the fusion of the alloy; and on opening it again, each of the cupels is found to contain a bright convex metallic globule, in which state the assay is said to be *uncovered*. The air is now freely admitted, and rapidly converts the lead into litharge, which, as fast as it is produced, is absorbed by the bone-ash of the cupel. While this operation is going forward, the rounded surface of the liquid button appears to be covered with bright patches and lines of color; these are produced by the thin film of oxide of lead which is constantly forming, and passing off from the centre to the edges of the assay, where it meets with and sinks into the porous matter of the cupel, leaving always a new surface exposed to the current of air which is carried by the draught through the muffle. At the same time there rises, and passes through the openings of the muffle, a white vapor, which is caused by the volatilization and combustion of a portion of lead. When this vapor is very thin, and rises with great rapidity, it is an indication that the heat is too great, and part of the draught must be stopped; on the other hand, when it is thick and heavy, and hangs sluggishly over and around the cupel, the temperature is too low, and the power of the draught must be increased.

As soon as the greater part of the lead has been thus converted into litharge and absorbed, the remaining bead of rich alloy appears to become agitated by a rapid circular movement, and the bands of color with which the surface is covered arise and vanish in quick succession. This is a sign that the process is on the point of completion, and means must now be taken to increase the heat of the furnace for a short time, so as to insure the expulsion of the last remaining portions of lead. But if silver be present in the assay, and if it be desired to estimate also the amount of that metal, the increase of temperature towards the end of the process must be of short duration, otherwise a portion of the silver would soon volatilize. Immediately before the conclusion of the process, the assay becomes somewhat dull, and the movements on its surface can no longer be observed; but after a few moments, it again suddenly lights up with a kind of flash or coruscation, and then becomes permanently brilliant and immovable, —assuming, in short, the fixed metallic lustre of pure melted gold or silver. If the cupellation has been well performed, the gold, or the mixture of the two precious metals, is now in a state of almost chemical purity.

When the phenomenon termed the *flashing, brightening*, or *coruscation* of the assay indicates that the cupellation is terminated, the mouth of the muffle ought to be closed for thirty or forty seconds, and then the cupel containing the button of pure metal may be drawn to the front of the muffle, and allowed to cool slowly. The refrigeration must not be too rapid, otherwise there may be very sensible loss by *spitting, sprouting*, or *vegetation*—an effect, however, only produced when a large proportion of silver is present, and which has been already explained in connection with the process of cupellation on the large scale. To insure gradual cooling, it is occasionally convenient to invert over the cupel containing the bead another heated cupel.

The button is detached from the cupel after cooling

by a pair of fine steel forceps, and gently squeezed between the jaws of a pair of pliers, to loosen and pulverize any adhering litharge, which is finally cleaned off with a small brush made of brass wire or stout bristles. If the process has succeeded, the button should be round and bright upon its upper surface, but somewhat rough or crystalline on the part by which it was attached to the cupel, from which it ought to be capable of being removed without difficulty.

Even after cupellation, there always remains a trifling admixture of copper in the assay, which is called the *surcharge*, unless there has been present a sufficient proportion of silver. This metal greatly facilitates the separation of the copper, and when it is present in the proportion of three parts of silver to one of gold, the copper can be completely separated. This is one important reason for adding the requisite amount of silver before cupellation. But although silver is not appreciably oxidised or volatilized when melted alone, yet it is so to a certain extent in cupellation; in consequence of the presence of lead. It is, therefore, necessary to make cupellations of the buttons from ores containing silver, at the lowest heat at which the absorption of the litharge can be readily determined. But even when every precaution is used, there is always a loss of silver in cupellation; and the amount of this loss under varying conditions must be known, so as to be able to supply the deficiency in the calculation of the per-centage, as well as with a view to the next process of *parting*. The following table has been calculated for this purpose. The first column gives the weight of silver in one thousand parts of an alloy of silver and copper about to be submitted to cupellation; the second, the actual weight of silver found by cupelling an alloy of silver and copper containing the weight of silver indicated in the corresponding line of the first column; and the third, the actual loss in weight of silver:—

Weight of silver before cupellation	Weight of silver after cupellation	Loss of silver
1000	998.97	1.03
975	973.24	1.76
950	947.50	2.50
925	921.75	3.25
900	896.00	4.00
875	870.93	4.07
850	845.85	4.13
825	820.78	4.22
800	795.70	4.30
775	770.59	4.41
750	745.48	4.52
725	720.36	4.64
700	695.25	4.75
675	670.27	4.73
650	645.29	4.71
625	620.30	4.70
600	595.32	4.68
575	570.32	4.68
550	545.32	4.68
525	520.32	4.68
500	495.32	4.68
475	470.50	4.50
450	445.69	4.31
425	420.87	4.13
400	396.05	3.95
375	371.39	3.61
350	346.73	3.27
325	322.06	2.94
300	297.40	2.60
275	272.42	2.58
250	247.44	2.56
225	222.45	2.55

Weight of silver before cupellation	Weight of silver after cupellation	Loss of silver
200	197.47	2.55
175	173.88	2.12
150	148.30	1.70
125	123.71	1.29
100	99.12	.88
75	74.34	.66
50	49.56	.44
25	24.78	.22

In assaying native gold or artificial alloys, the operation usually commences by fusing the alloy in a cupel with about five times its weight of pure lead, and then adding the amount of pure silver necessary to bring the mixture to the proper composition. If the substance be in the ordinary state of the gold of California or Australia, that is, in small grains or dust, it is the best plan to envelop it in a thin sheet of lead; or a suitable quantity of perfectly pure lead may be put into the cupel and melted, and then the assay, wrapped up in a piece of thin sheet assay-lead, may be gently added to the melted lead upon the cupel. Finally, add about three times the weight of the assay in pure silver, and then proceed with the cupellation in the manner above-described. The presence of iron, tin, nickel, or zinc, in the alloy under assay, materially interferes with the success of the operation, as these metals will not pass into the cupel by the aid even of a large quantity of lead; but from their rapid oxidation, will either volatilize, or will accumulate on the surface as a sort of slag, in which particles of precious metal may be entangled. In this case the assay becomes what is technically termed *foul*, the cupel not being able to absorb the metallic oxides as fast as they are formed. To obviate this evil, the preliminary process of scorification should be resorted to, when the presence in the alloy of any of the above metals is known or suspected. A convenient weight of native gold or rich alloy to operate upon is ten to fifteen grains. *

Bismuth might be used as a substitute for lead in cupellation, two parts of it being nearly equivalent to three of lead; but its higher price prevents its general use for this purpose. The lead employed must be in all cases entirely free from silver, being such as has been revived from pure litharge, otherwise it would be quite impossible to estimate the true composition of the alloy. The assay of gold furnishes results which are more accurate than those obtained in the cupellation of silver; the loss of gold by volatilization is very much smaller, and scarcely any of the metal is carried into the cupel by an excess of lead.

Parting of the Assay.—After the preceding operations, the button of alloy which remains is composed of gold and silver, not, indeed, absolutely pure, for, whatever precautions may be used, it will still retain a small quantity of lead, and frequently, also, traces of copper. For practical purposes, however, it may be regarded as a pure alloy of the two precious metals, and in this view it now only remains to separate the gold from the silver. It has been stated that, on the Continent, this is effected on the large scale by means of sulphuric acid, which, at its boiling temperature, possesses the property of dissolving silver without acting upon gold. For analytical purposes, however, nitric acid is preferred, and is generally employed in this

country, even for refining operations on the large scale.

It has been stated, also, that when silver and gold are intimately mixed together, as in an alloy, it is necessary that the silver should be present in the proportion of at least two and a half parts of that metal to one part of gold, otherwise its particles will be so enveloped and protected by those of the gold, that the nitric acid will be prevented from exercising its solvent action upon them. If, as is generally the case, the requisite proportion of silver has been introduced before cupellation, or if it is known to exist in the alloy in that proportion, then it will be sufficient to subject the mixture at once to the action of the acid. But if the silver be present in a less or much greater proportion, then, as a preliminary step to the operation of parting, the alloy must be brought to the proper standard, either by the addition of the necessary quantity of pure silver, or by adding more gold, as the case may be; for if the proportion of silver exceed three parts, the gold will be precipitated by the acid as a dark powder, instead of retaining the more convenient form of the alloy subjected to treatment; and thus an accurate estimation of the amount of gold present will be rendered considerably more difficult.

On the whole, the operation of parting is found to succeed best when the alloy contains a little less than three parts of silver to one of gold. Hence, in all cases where much exactness is required, the addition of silver, if necessary, must be so managed as to agree as closely as possible with this proportion; and from the circumstance, that when the relative quantities of the two are so adjusted, the gold is present in the proportion of about one-fourth of the mass, and the silver in the proportion of three-fourths, the operation of bringing the alloy to the proper standard by the requisite addition of the latter metal, is termed *inquartation*. The quantity of silver required can only be known by a previous approximate experiment by the wet method of examination, or by the use of the touchstone.

Assuming that the proper proportion already exists in the button of gold and silver obtained by cupellation, it is first hammered out upon an anvil into a small disc about the size of a sixpence, and annealed by heating it to redness. It is then passed between a pair of laminating rollers, by which its thickness is reduced to that of an ordinary address card, or about one-eightieth of an inch, after which it is a second time annealed. These operations render it sufficiently flexible to allow of its being twisted into a small spiral coil or *cornet*,

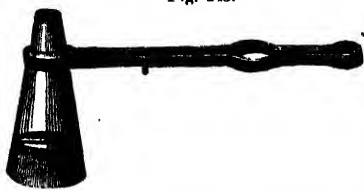


Fig. 243.

contains about an ounce of nitric acid of specific gravity 1.180. The acid must be perfectly free from chlorine, and must always be carefully tested to ascertain this point by adding to it a drop of solution of nitrate of

silver, which, if chlorine be present, will instantly render it milky. Instead of the flask represented in Fig. 243, a small bulb-shaped matrass is frequently used, and is now generally adopted by the best assayers of bullion, both on the Continent and in this country. Common Florence oil flasks, or smaller vessels of the forms represented in Figs. 244 and 245, will be found very convenient. When the

cornet has been introduced, the flask with its contents is gently heated to nearly the boiling-point. Effervescence will now take place, with a brisk evolution of nitrous fumes, and the silver will be gradually dissolved, leaving the gold in the form of the original cornet, but porous, very brittle, and of a deep blackish-brown color. When the effervescence has entirely ceased, the flask is removed from the heat, and the solution is carefully decanted off, without letting the cornet of gold fall out. The latter is then washed by pouring distilled water upon it, which, after standing for a couple of minutes, is again poured off. The gold will still retain some traces of silver, and in order to remove these, the cornet is again boiled with stronger nitric acid, of specific gravity 1.280, and this operation may even be repeated a third time, to remove the last portions of silver, which exist as a surcharge. In the second and third boilings, which may each be continued for ten or fifteen minutes, it is well to introduce into the flask a small fragment of charcoal, to prevent the ebullition from taking place with sudden bursts, otherwise the action may be so violent as to break the cornet, which it is desirable to avoid.

The last acid having been poured off, the flask is completely filled with distilled water, and a small, smoothly-finished, porous clay crucible is placed over the mouth of it. The two vessels, thus adjusted, are then inverted, so as to allow the cornet to fall gently through the water into the crucible, and by a dexterous movement of the hand the flask is withdrawn, in such a manner as to prevent the overflow of any liquid from the little crucible. The latter is now carefully decanted into the vessel containing the silver solution, and the crucible containing the cornet is heated to redness in the muffle. Under this final heating it is not fused, but shrinks in bulk, loses its brown appearance, and assumes the peculiar color and lustre of gold: while at the same time it is rendered more compact, less brittle and fragile, and when cold, can now be removed by a pair of forceps to the scales, in which it is weighed with the same precision and care as the original alloy.

The weight of the cornet will indicate very nearly the amount of gold in the alloy if the assay has been properly conducted, but not with absolute exactness. Even when every precaution has been used, the gold contained in the cornet is never chemically pure; it still retains a very small quantity of lead and of silver, and frequently also traces of copper, in consequence of which the weight of the cornet may exceed by one two-thousandth part the true result; and when it is considered that, in assaying alloys, the quantity taken

Fig. 244. Fig. 245.



is usually not more than seven or eight grains, it will be seen that even this small error might lead to serious disappointment in estimating the proportion of gold in large masses of bullion. To ascertain the amount of the error, and thus to arrive at a perfectly correct estimate, it is usual to pass through the muffle, simultaneously with the alloys, a number of what are termed *proofs*, consisting of weighed portions of perfectly pure gold, to each of which is added a proportion of copper equal to that estimated to exist in the alloys under examination. The cornets obtained from these proof-assays are weighed, and the excess of weight over that of the gold which was introduced, indicates the amount of the correction which it becomes necessary to make for the other assays. This correction is liable to variation, according to the temperature of the furnace, and other causes; but it usually ranges from 0.2 to 0.5 in 1000.

If the quantity of silver in the alloy submitted to the operation of parting exceed by more than thrice the weight of the gold, the separation may still be effected by nitric acid, but the gold will be left in a state of powder. It may, however, be washed, ignited, and weighed in the manner described in connection with the quantitative estimation of gold by the wet method, and also in the process of parting with sulphuric acid on the large scale. Should the amount of silver be but small compared with the gold, and the assayer wish to avoid the trouble of inquartation, the alloy may at once be subjected to the action of aqua regia, when the gold will be dissolved, and the silver will be thrown down as an insoluble chloride. The clear solution containing the gold is then decanted, and when the excess of acid has been expelled by evaporation, the gold can be precipitated, as already described, by sulphate of iron.

The silver contained in the solution of the nitrate of that metal obtained in the common process of parting, may readily be recovered by adding an excess of chloride of sodium, which will throw down the whole of the silver as white insoluble chloride. This precipitate, which speedily becomes slate-colored on exposure to light, is collected, and put into a vessel containing water acidulated with hydrochloric acid; some zinc or iron is introduced, and the silver is rapidly restored to the metallic state, in the form of a dark-grey powder. When this powder is washed with water, dried, and fused in a crucible, the silver assumes its natural appearance, but is very brittle. Its malleability is restored, however, by simply re-melting.

PHYSIOLOGICAL EFFECTS, et cetera.—Gold, says PEREIRA, like other metals, has been frequently supposed to be inert while it retains its metallic condition, but in this, as well as in some other instances, the accuracy of the assumption has been denied. Both CHRESTIEN and NIEL, as well as other writers, assert that finely-divided metallic gold—*pulvis auri*—produces the same constitutional effects as those caused by the various preparations of this metal, but in a milder degree, while it excites little or no irritation. It is said to promote the secretions of the skin, kidneys, and salivary glands.

It has been employed as an antivenereal and anti-scrofulous remedy, by CHRESTIEN, NIEL, and others,

with considerable success. It is said to be preferable to the other preparations of this metal in delicate and nervous subjects, females and infants. Gold-leaf—*aurum foliatum* sen *lamellatum*—is used by dentists for filling decayed teeth, and was formerly employed by apothecaries for covering pills—*ad incutandas seu obducendas pilulas*. Silver-leaf now takes its place. It has been administered internally in doses of from a quarter of a grain to a grain three or four times a day. CHRESTIEN used it by way of friction on the tongue and gums. NIEL employed it endermically—that is, applied it to the skin deprived of the epidermis—in the form of ointment composed of one grain of gold and thirty grains of lard.

Teroxide of gold is sometimes used internally, in venereal and scrofulous diseases, in doses of from one-tenth of a grain to a grain, made into the form of pills with mezercon.

The terechloride of gold, the preparation of which is described at page 293, acts, according to ORFILA, as a corrosive when introduced into the stomach of animals, but with less energy than the chloride of mercury, and destroys them by the inflammation of the coats of the alimentary canal which it sets up.

On man its effects are analogous to those of chloride of mercury. In *small doses* it acts, according to Dr. CHRESTIEN, more energetically as a stimulant, though less powerfully as a sialogogue, than corrosive sublimate. It promotes the secretions of the skin, the salivary glands, and the kidneys. Taken to the extent of one-tenth of a grain daily, it has occasioned violent fever. CULLERIER has seen one-fifteenth of a grain excite, at the second dose, gastric irritation, dryness of the tongue, redness of the throat, colic, and diarrhoea. When it promotes the secretion of saliva, it does not as mercury affect the teeth and gums. MAGENDIE has seen violent gastritis, accompanied by nervous symptoms—cramps and pains in the limbs, agitation and loss of sleep—and afterwards great heat of skin, and obstinate sleeplessness. In *large doses*, it would probably occasion symptoms similar to those produced by the use of poisonous doses of chloride of mercury.

It has been employed, with variable success, as a substitute for mercury in the secondary symptoms of syphilis. A more extended experience of it is, however, necessary to enable one to speak of its remedial powers with confidence. In the hands of CHRESTIEN, NIEL, CULLERIER, LEGRAND, and others, it has proved most successful.

It has also been used in scrofulous affections, bronchocele, chronic skin diseases, scirrhus tumours, et cetera. DUFOUR cured with it a case of obstinate ulceration of the face, regarded by him as cancerous and which had resisted all the ordinary methods.

LEGRAND has used terechloride of gold, acidified with nitric acid, as a caustic in syphilitic, scrofulous, and scorbutic ulcers, cancerous growths, and ulcerations of the neck of the uterus.

Internally, it has been given in doses of one-twentieth of a grain, made into pills with starch. But as organic matters decompose it, it is better to use it in distilled water, or to apply it by friction to the mouth, in quantities of from one-sixteenth to one-sixth of a grain.

The whites and yolks of eggs, milk, and a mixture of wheat-flour, oatmeal, or barley, and water, are, as in the case of chloride of mercury, antidotes for an overdose of this auric compound.

The Editor is surprised to find that the above are so little used in medicine. Surely, if physicians would only daily experiment on the action of the different metals and their compounds upon the system, they might soon discover some more very valuable specifics.

STATISTICS.—Gold and silver are frequently confounded in statistical returns under the common designation of the *precious metals*; and even where the two are classed separately, it is still desirable to place them in juxtaposition, since much of the interest attaching to the subject is derived from the relation which they bear to each other. In proceeding, therefore, to state the most important facts connected with the statistics of gold, the Editor will give, at the same time, most of the corresponding facts and figures relating to silver; which will not only save the repetition of a number of tables nearly similar, but will furnish the reader with a clearer and more satisfactory view of the subject, than if the returns relating to each of the metals were tabulated separately in different parts of the work.

Much interesting information relating to the history and statistics of the precious metals is given in a work which was published by Mr. JACOB in 1831, in which he takes up the subject at the earliest period, and continues it to the year above-mentioned. Mr. JACOB shows that, in the days of Roman supremacy, the greater part of the wealth of the world continued to flow into Rome, up to the time of AUGUSTUS, when the production of gold from the Roman mines in Illyria and Spain suddenly ceased; and for a long period the world received no new accession of metallic wealth. With much labor and research, he constructed a table showing the rate of diminution to which the enormous wealth of the Augustan period was subject; and though it includes both gold and silver under one head, while at the same time its accuracy cannot be implicitly relied on, still it is sufficiently correct and instructive to merit a place in these pages:—

QUANTITY OF GOLD AND SILVER IN THE ROMAN EMPIRE.

Year.	
14	2358,000,000
50	322,200,000
86	287,980,000
122	259,182,000
158	233,263,800
194	209,937,420
230	181,943,678
266	163,749,311
302	147,374,380
338	132,636,942
374	119,373,248
410	107,435,924
446	96,092,332
482	87,033,099
518	78,229,700
554	70,406,730
590	63,364,057
626	57,027,652
662	51,324,887
698	46,192,399
734	41,573,160
770	37,415,840
806	33,674,256

From the decline and fall of the Roman empire, the

portion of gold added to that already obtained was, for many centuries, not more than sufficient to supply the annual waste by wear and loss; and except the mines of Hungary and Sweden, which do not appear to have been worked before the eighth or ninth century, no important new sources of gold were opened until the discovery of America by COLUMBUS in 1492. This event was followed, in the course of the next century, by a considerable influx of the precious metals into Europe; yet a very superficial inquiry will suffice to show, that the actual amounts which were imported from Mexico and South America have been greatly exaggerated in the public mind, and sink into very humble figures when compared with the enormous treasures obtained within the last few years from California and Australia. From 1492 to 1500, America, according to HUMBOLDT, furnished to Europe, in gold and silver, not more than fifty-two thousand pounds sterling, and the entire annual amount of gold and silver obtained from America during the sixteenth century was only about half a million sterling; whereas, for the last few years, the value of *gold alone* exported from California and Australia has averaged twenty-four millions per annum. The celebrated *El Dorados* of the sixteenth century sink, therefore, into utter insignificance, compared with the recently-developed auriferous regions.

It is true, that with the discovery of the Brazil mines and other sources, the import of the precious metals from America continued steadily to increase; and from 1600 to 1700, during which period Europe obtained its supply of gold almost exclusively from the New World, the mines of the latter were estimated to have produced an amount of gold and silver equivalent to three hundred and thirty-seven millions, five hundred thousand pounds sterling, or upwards of three millions per annum. In consequence of this continued importation, the value of the coined money in Europe in 1699 has been estimated at two hundred and ninety-seven million pounds sterling. During the eighteenth century, the supply of the precious metals was still chiefly derived from the Americas. The annual produce of the mines of that quarter of the globe, at the commencement of the present century, was estimated by HUMBOLDT at eight millions, seven hundred thousand pounds sterling; and that derived from the European mines of Hungary, Saxony, *et cetera*, and those of Northern Asia, was valued by him at one million pounds sterling more, raising the total produce at that period, exclusive of Africa, to nine million seven hundred thousand pounds sterling. The *quantity* of gold produced in America was to the *quantity* of silver as 1 to 46; in Europe as 1 to 40; and the *values* of equal quantities of gold and silver were then in the proportion of 15 to 1, so that the aggregate value of the gold to that of the silver was nearly as 1 : 3; or, in other words, the annual amount of *gold alone* produced at the beginning of the present century was worth about three million two hundred thousand pounds sterling.

From 1800 to 1810 the yield of the American mines continued still to increase, and, in conjunction with that of the European and Russian mines, is supposed to have amounted in the latter year to upwards of eleven million pounds sterling, in gold and silver. But in that

year began the contest which resulted in the dissolution of the connection between Spain and her American colonies, causing the abandonment of several of the mines, and a consequent decline in the production of the precious metals to such an extent, that, according to JACOB, the total average yield of the American mines, inclusive of Brazil, during the twenty years ending with 1829, might be estimated at little more than four million pounds sterling a year; being less than half their produce in 1800. Some years later, however, they again began to increase; and this, in conjunction with the recent extraordinary development of the Russian

mines, raised the entire amount of gold and silver produced from all the *known* auriferous localities throughout the world, *before the discovery of California and Australia*, to upwards of twelve million pounds sterling per annum; the value of the gold to that of the silver being nearly as 5 : 6. This will appear from the following table, prepared by Mr. BIRKMYRE, showing, by approximate calculation, the annual produce in value of fine gold and silver for 1846 and 1850; the first being two years before the discovery of the rich deposits of gold in California, the latter two years after the discovery:—

Countries.	1846.			1850.		
	Gold.	Silver	Total.	Gold	Silver.	Total.
	£	£	£	£	£	£
California,.....	—	—	—	12,000,000	62,088	12,062,088
United States,.....	237,336	1,864	239,230	115,430	11,444	126,874
Mexico,.....	249,753	3,457,020	3,706,773	382,901	5,383,333	5,766,234
New Grenada,.....	252,407	42,929	295,336	252,407	42,929	295,336
Peru,.....	96,241	1,000,583	1,096,824	96,241	1,000,583	1,096,824
Bolivia,.....	60,337	460,191	520,548	60,337	460,191	520,548
Chili,.....	145,585	297,029	442,614	145,585	297,029	442,614
Brazil,.....	259,871	2,603	261,874	289,068	2,227	291,295
Total of North and South America,....	1,301,560	5,261,619	6,563,179	13,341,989	7,259,824	20,601,813
Russia,.....	3,414,427	167,831	3,582,258	4,175,860	171,817	4,347,477
Norway,.....	—	32,346	32,346	—	35,607	35,607
North Germany,.....	357	138,022	138,379	357	138,022	138,379
Saxony,.....	—	198,200	198,200	—	198,200	198,200
Austria,.....	282,750	282,654	565,404	288,708	286,971	575,679
Piedmont,.....	17,841	7,444	25,285	17,841	7,444	25,285
Spain,.....	2,498	227,499	229,997	2,498	440,210	442,708
United Kingdom,.....	—	109,989	109,989	—	160,000	160,000
Africa,.....	203,900	1,056	204,956	203,900	1,056	204,956
Borneo,.....	305,900	1,584	307,484	305,850	1,584	307,484
Ava,.....	100,000	517	100,517	100,000	517	100,517
Malacca,.....	72,240	374	72,614	72,240	374	72,614
Sumatra,.....	63,719	330	64,049	63,719	330	64,049
Annam or Tonquin,.....	30,585	53,460	84,045	30,585	53,460	84,045
Various countries,.....	50,975	33,000	83,975	50,975	33,000	83,975
Total of Europe, Africa, and Asia,....	4,545,192	1,254,306	5,799,498	5,312,533	1,528,592	6,840,975
Total of North and South America,....	1,301,560	5,261,619	6,563,179	13,341,989	7,259,824	20,601,813
Total,.....	5,846,752	6,515,925	12,362,677	18,654,522	8,788,416	27,442,788

The various countries are exclusive of China and Japan, which produce large quantities of gold and silver, the amount of which is quite unknown to Europeans.

It will be seen from the above table, that in 1846 the total value of the gold is estimated at five million, eight hundred and forty-six thousand, seven hundred and fifty-two pounds sterling; in 1850, it rises to eighteen million, six hundred and fifty-four thousand, five hundred and twenty-two pounds sterling. Mr. BIRKMYRE, however, estimates the produce of California alone in the last-mentioned year at twelve million pounds ster-

ling—a figure so high that, notwithstanding the importance attached by MACCULLOCH to his calculations, it seems to have far exceeded the truth. This may be inferred from the following table, extracted from the *Economist* newspaper, which has the credit of deriving its statistical information from the highest official sources:—

TOTAL VALUE OF GOLD EXPORTED FROM AUSTRALIA AND CALIFORNIA IN EACH YEAR FROM 1848 TO 1856 INCLUSIVE.

Year.	New South Wales	Victoria.	California	Total.
1848	—	—	£11,700	£11,700
1849	—	—	1,600,000	1,600,000
1850	—	—	5,000,000	5,000,000
1851	£468,336	£438,777	8,250,300	9,157,413
1852	3,600,175	6,135,728	11,700,000	21,435,903
1853	1,781,171	8,664,729	12,500,000	22,945,700
1854	773,209	8,255,550	14,100,000	23,128,759
1855	209,250	11,303,980	13,400,000	24,913,230
1856	97,456	12,643,024	14,000,000	26,740,480
Total,.....	£6,929,597	£47,441,588	£80,562,000	£134,933,185

To bring down the accounts to the latest date, the following table of imports, also resting on high authority, may be added:—

IMPORTS OF GOLD AND SILVER INTO GREAT BRITAIN FOR THE FIRST SIX MONTHS OF THE YEAR 1857 WERE—

From	
Africa.....	gold £52,000
United States, including principal imports from California.....	3,252,000
Australia.....	5,833,000
Brazils.....	6,000
Mexico, West Indies, Peru, and a portion from California.....	gold and silver 3,415,000
Mediterranean.....	543,000
Russia.....	119,000
	£13,220,000

It will be observed, however, that these figures include both silver and gold, and indicate merely the amount of the precious metals imported into this country. But when it is considered that nearly the whole of the Australian produce is in gold, and that it is almost exclusively exported to Great Britain, the amount above stated as having been imported from that part of the world during the first six months of the present year, seems to indicate a falling-off as compared with the amount exported in 1856. This decline has been acknowledged by Australian journalists, but is attributed to temporary causes—the employment of larger numbers of the mining population than at any former period in deep sinking and in quartz mining, their consequent withdrawal from the immediate production of gold, and the protracted dryness of the season. The same writers affirm, that when the labor of the deep sinkers has been consummated, and the hoards of the shallow sinkers have passed through the process of washing, the average of the returns of the current year will be brought up to that of last. The steadiness with which the quartz reefs are being opened up at a heavy cost of labor and of money, and the large sums expended in machinery for the extraction of the metal, are deemed sure indications of the faith entertained by practical men in the hidden riches of the Australian gold mines.

On the whole, the present annual supply of gold may be roughly estimated as follows:—

Asiatic Russia.....	£4,000,000
Rest of Asia—exclusive of Japan and China.....	500,000
Europe.....	300,000
Africa.....	200,000
North and South America—exclusive of California.....	1,500,000
California.....	14,000,000
Australia.....	13,000,000
Total.....	£33,500,000

The annual consumption of *gold and silver* in the arts, and as coin or currency, is estimated by MACCULLOCH as follows:—

Wear and tear and loss of coin.....	£5,700,000
Increase of currency.....	11,400,000
Used in the arts.....	11,200,000
Total.....	£28,300,000

In connection with the subject of coinage, it may not be out of place to append the following tables, which would be obviously divested of much of their interest by giving the gold coinage alone:—

I. AMOUNT OF GOLD, SILVER, AND COPPER MONIES COINED AT THE ROYAL MINT, LONDON, FROM 1840 TO 1856.

Years	Gold.	Silver.	Copper.	Total.
1840 ..	Nil	£216,414	£3,136	£219,550
1841 ..	£378,472	96,175	8,848	483,495
1842 ..	5,977,051	192,852	1,764	6,171,667
1843 ..	6,607,849	276,606	10,080	6,894,535
1844 ..	3,563,949	626,670	7,246	4,197,865
1845 ..	4,244,608	647,658	6,944	4,899,210
1846 ..	4,334,911	559,548	6,496	4,900,955
1847 ..	5,158,440	125,730	8,960	5,293,130
1848 ..	2,451,999	35,442	2,688	2,490,129
1849 ..	2,177,955	119,592	1,792	2,299,339
1850 ..	1,491,836	129,096	448	1,621,380
1851 ..	4,400,411	87,868	3,584	4,491,863
1852 ..	8,742,270	189,596	4,312	8,936,178
1853 ..	11,952,391	701,544	10,190	12,664,125
1854 ..	4,152,183	140,480	61,538	4,354,201
1855 ..	9,008,663	195,510	41,091	9,245,264
1856 ..	6,002,114	462,528	11,418	6,476,061

II. COINAGE OF FRANCE IN EACH YEAR FROM 1846 TO 1856 INCLUSIVE, CONVERTED INTO BRITISH MONEY AT THE RATE OF TWENTY FIVE FRANCS TO THE POUND STEELING.

Years.	Gold.	Silver.	Total
1846	£88,000	£1,332,000	£1,420,000
1847	300,000	2,760,000	3,060,000
1848	1,600,000	4,040,000	5,640,000
1849	1,089,000	7,360,000	8,440,000
1850	4,600,000	3,120,000	7,720,000
1851	9,600,000	2,360,000	11,960,000
1852	1,040,000	2,840,000	3,880,000
1853	13,200,000	800,000	14,000,000
1854	20,480,000	80,000	2,056,000
1855	16,417,928	862,800	17,280,728
1856	20,334,076	2,168,888	22,502,964

III. ACCOUNT SHOWING THE AMOUNT OF COINAGE IN THE UNITED STATES IN 1855, CONVERTED INTO BRITISH MONEY AT THE RATE OF FOUR SHILLINGS AND THREE-PENCE TO THE DOLLAR.

Mints	Gold.	Silver
Philadelphia.....	£2,251,321	£301,574
New Orleans.....	95,731	407,575
San Francisco.....	3,739,639	34,228
Dahlonaga.....	21,815	—
Charlotte.....	46,311	—
Total.....	£6,157,817	£743,377

IV. BULLION EXPORTED FROM ENGLAND AND THE MEDITERRANEAN PORTS TO THE EAST—1852 TO 1856.

Years	Gold	Silver	Total
1852	£761,318	£2,491,137	£3,255,455
1853	986,574	5,695,602	6,682,176
1854	1,222,755	4,583,017	5,805,772
1855	1,191,511	7,931,129	9,125,640
1856	478,788	14,108,901	14,587,689
Total.....	£1,640,946	£34,815,786	£39,456,732

Annexed are some of the rates of value of a pound troy of gold at different periods:—

VALUE OF THE TROY POUND OF GOLD.

Years.	
1344	£15 0 0
1345	13 3 4
1347	14 0 0
1412	16 13 4
1464	20 16 8
1526	27 0 0
1549	34 0 0
1605	40 10 0
1626	44 10 0
1718	46 14 6
1817	46 14 6

which is the price at which fine gold still continues, or three pounds seventeen shillings and tenpence half-penny per ounce.

Mr. HUNT states, that for the uses of the arts not less

than one thousand ounces of fine gold are used in Birmingham alone every week, and that in the United Kingdom the weekly consumption of leaf-gold is as follows:—

	Ounces weekly
London,	400
Edinburgh,	35
Birmingham,	79
Manchester,	40
Dublin,	12
Liverpool,	15
Leeds,	6
Glasgow,	6
Total,	584

Of this amount, he states, on the authority of an eminent gold-refiner, that not one-tenth part can be recovered; and he adds, that for gilding metals by the electrolyte, and the water or wash-gilding processes, not less than ten thousand ounces of gold are required annually. One establishment in the Potteries employs three thousand five hundred pounds' worth of gold per annum, and nearly two thousand pounds' worth is used by another. The consumption of gold in the Staffordshire Potteries for gilding porcelain and making crimson and rose color, varies from seven thousand to ten thousand ounces per annum.

The Editor has to express his obligations to Mr. GEORGE BLAIR of Glasgow for his valuable aid during the compilation of this article.

GUMS.—*Gommes*, French; *Pflanzenschleimen*, German; *Gummi*, Latin.—Under the term gum, says BRANDE, are included several modifications of a distinct proximate principle of vegetables, which are of extremely common and almost universal occurrence. To some of these, the term *mucilage* is occasionally applied.

They are characterised by forming a viscid, mucilaginous, or adhesive solution with water, and by insolubility in alcohol, so that the addition of the latter to a moderately strong aqueous solution of gum occasions the separation of a white precipitate or magma. Another characteristic of gum is its convertibility into mucic or saccharic acid by the action of nitric acid.—*Brande*.

Gum is found upon the bark of certain trees as an exudation, which gradually concretes in transparent or translucent amorphous drops. It may also be detected, in greater or less quantity, in the juices of most plants and fruits.

The several species of gums are distinguished by their behavior with water. Some dissolve in that liquid, and form *mucilages*, as gum-arabic; while others soften and intumesce, as tragacanth. But there is also an intermediate kind, represented by cherry-tree gum, which is only partially dissolved in water. These different classifications of gums have been denominated *arabin*, *tragacanthin*, and *cerasin*—from the Latin *cerasus*, a cherry-tree.

GUM-ARABIC—*Gomme Arabique*, French; *Arabischegummi*, German; *Gummi Acacia*, Latin—is the produce of the *Acacia Vera Arabica*, and other varieties. Many have supposed the *shittah* tree, mentioned in many parts of the Old Testament, especially in connection with the building of the tabernacle, to have been an acacia; some have regarded it as the *A. Vera*,

while others have thought it to have been the *A. Horrida*.

Dr. ADAM CLARKE, in his comment on Exodus, xxv. 5, says:—The *Acacia Nilotica*, or *A. Arabica*, is known to have been plentiful in Egypt, and it abounds in Arabia Deserta, the very place in which MOSES was when he built the tabernacle; and hence it is reasonable to suppose that he built it of that wood, which was every way proper for his purpose, being solid, light, and very beautiful.

HIPPOCRATES mentions *Egyptian acacia*, and the *white acacia*, by which, it is supposed, he meant the *acacia vera*. DIERBACH, however, thinks that the *Acacia Senegal* is referred to, from the fact that the wood, bark, and flowers of the latter are white. Gum is also named by HIPPOCRATES as being employed in medicine.

PRODUCTION.—The gum of the acacia trees flows, in the liquid state, from the trunk and branches, and hardens by exposure to the air. It usually exudes spontaneously, but, in some instances, the discharge is facilitated by incisions. In Barbary, the largest quantity of gum is procured during the hot and parching months of July and August. The more sickly the tree appears, the more gum it yields; and the hotter the weather, the more prolific is it. A wet winter and a cool or mild summer are unfavorable to the production of gum. In Senegal the gum begins to flow when the tree first opens its flowers, and it continues during the rainy season till the month of December, when it is collected for the first time. Another gathering of the gum is made in the month of March from incisions in the bark, which the extreme dryness of the atmosphere at that time is said to render necessary.—*Pereira*.

DESCRIPTION.—Gum-arabic occurs in globular pieces or *tears*, which are colorless or light yellow, more or less transparent, inodorous, and somewhat brittle. The following description of the most important varieties of acacia gum, is extracted from PEREIRA'S *Materia Medica*:—

Turkey or Arabic Gum is imported from Leghorn, Malta, Trieste, Gibraltar, Smyrna, Alexandria, Constantinople, &c. &c., and is the produce of the *Acacia Vera*, and probably of other species, especially *A. Arabica*. It occurs in rounded tears, or amorphous or angular fragments, varying from the size of a pea to that of a walnut, or even still larger; some of the pieces being transparent, others more or less opaque, from innumerable cracks extending through them. It has a glassy lustre, is white, yellow, or sherry colored, and has no odor, or, if any, an acid one. Its specific gravity varies from 1.316 to 1.482. It is entirely soluble in water, the solution having the property of reddening litmus, and being feebly opalescent. The latter characteristic is said by GUERIN to be owing to the presence of a small quantity of insoluble nitrogenous matter.

Barbary or Morocco Gum is imported from Mogadore and Mazagan. It is probably the produce of *Acacia Gummifera*. Dr. PEREIRA had two varieties of Barbary gum; one in roundish or irregular tears, mixed with many impurities, imperfectly transparent, and of a dull yellowish color, with a faint tint of green. It

was not wholly soluble in water. The other kind, called Mogadore gum, is in small, irregular, broken, mostly yellow pieces, which resemble fragments of Turkey gum.

Gum-senegal is imported from St. Louis, St. Mary's, the river Gambia, Senegal, and Bathurst, and is probably obtained from several species of acacia; but especially *A. Senegal*, *A. Vera*, *A. Serjal*, and *A. Adansonii*, are said to produce it in part. It occurs in larger tears than those of Turkey or Arabic gum, and large air cavities are frequently found in their centres on breaking them. Whitish pieces are occasionally met with, but for the most part they are yellow, reddish-yellow, or brownish-red. More difficulty is experienced in breaking or pulverizing this gum than gum-arabic, and its fracture is more conchoidal. GUIBOURT distinguishes two varieties of this gum: the first, gum-senegal, properly so called, probably the produce of *Acacia Senegal*; while the second, gum-galam, is yielded by *A. Vera*. There is but little difference between them, yet the latter has a greater resemblance to Turkey gum than the former. The pieces of gum-galam are more broken, and therefore more brilliant than those of gum-senegal. Those tears or fragments which have on some part of them a yellowish opaque skin or pellicle, constitute the *Gomme pelliculée* of GUIBOURT. The *Marrons de Gomme*, or *Gomme lignivole* of the same pharmacologist, is also found in the Senegal gum of commerce; it consists of yellowish or dark-brownish pieces, which are difficult to break, opaque, and rough. Treated with water, it is only partially dissolved. GUIBOURT states, that in most of the *marrons* he found a large ovoid cell, which had evidently been the habitation of some larvæ, whence he concludes that this substance is the work of an insect.

East India Gum is imported principally from Bombay, and is most likely the produce of various species. Many pieces—yellow East India gum—agree in their physical and chemical characters with Turkey gum, and are probably the produce of *Acacia Arabica*, or some allied species. Others, however, are larger, red, or brown—brown East India gum—and more difficult to pulverize than Turkey or Arabic gum.

Cape Gum is imported from the Cape of Good Hope; BURCHELL states that it is obtained from a species of acacia, closely resembling *A. Vera*, and which he denominates *A. capensis*. Notwithstanding that the last-named authority asserts, that the Cape gum is in no way inferior to that from *A. Vera*, it is considered by English dealers as a very inferior kind. It is pale yellow, and apparently resembles Mogadore gum mentioned previously, or small fragments of Turkey gum. It is collected by the Caffres.

PROPERTIES AND COMPOSITION.—Gum-arabic dissolves both in cold and hot water. If this solution be allowed to evaporate spontaneously, the gum is left apparently dry, but, in reality, in a hydrated state, retaining about seventeen per cent. of moisture. If heated slightly above 212° , the color of the gum becomes yellow, and it has an acid taste. When distilled destructively, the products are empyreumatic oil, acid water, carbide of hydrogen, carbonic acid, and a charred mass; the latter leaving, upon ignition, about three per

cent. of inorganic matter, composed of carbonates of potassa and lime, with minute portions of chloride of potassium, oxide of iron, aluminum, magnesia, and silicic acid.

Gum is thrown down from its aqueous solution by alcohol as a white magma. Tribasic acetate of lead—but not the neutral acetate—occasions a white precipitate, which BERZELIUS denominated *gummide of lead*. A concentrated solution of sesquichloride of iron causes, when dropped into a gummy menstruum, a brownish translucent gelatinization. Silicate of potassa and oxalate of ammonia produce white deposits, the reaction with the latter being caused by the lime present. Caustic potassa, according to BERZELIUS, first causes in strong solutions of gum a coagulum, which gradually liquefies. A solution of borax occasions in that of gum-arabic, a coagulation which dissolves in free acid. Gum, in this instance, gives a reaction similar to that afforded by starch.

On the trituration of powdered acacia gum with a sufficient quantity of sulphuric acid to form a pasty mass, the mixture soon acquires a brown color; and if it is allowed to stand for about twenty-four hours, then liquefied with water, and carbonate of lime added to unite with the acid, the gum which remains dissolved is considerably changed in character and properties. If, on the contrary, sulphuric acid and gum be mixed, the latter is decomposed with evolution of sulphurous acid, and the production of artificial tannin and a scarcely appreciable amount of acetic acid. Upon adding water after this reaction, about thirty per cent. of carbon is deposited. The ebullition of gum with *very attenuated* sulphuric acid, gives rise to the formation of glucose or grape sugar.

Gum is decomposed by nitric acid, and, on the application of heat, nitric oxide is set free, and *muic acid* deposits as the temperature of the mass becomes reduced. On carrying the decomposition further, malic and oxalic acids may be detected.

According to VAUQUELIN, when a solution of gum is subjected to the action of a stream of chlorine gas, citric acid is formed; but this statement is very questionable. Chlorine is absorbed by powdered gum, causing the latter to soften and become brown. Hydrochloric acid is also absorbed by gum; the latter becomes brown and glutinous; and, on the addition of sulphuric acid to the magma, hydrochloric acid gas is evolved.

Gum has been analysed by BERZELIUS, PROUT, GUERIN, MULDER, and many others. The following are some of the results of the examination of gum-arabic:—

	Centesimally represented.		
	Berzelius	Prout	Mulder
Carbon,	41.906	41.4	45.10
Hydrogen,	5.788	6.5	6.10
Oxygen,	51.306	52.1	48.80
	100.000	100.0	100.00

The analyses of BERZELIUS and PROUT give rise to the formula, $C_{13}H_{13}O_{12}$. That deduced from the results of MULDER is $C_{13}H_{10}O_{10}$. But LIEBIG adopts the formula, $C_{12}H_{11}O_{11}$, and represents it as a hydrate of carbon, $C_{12}H_{11}HO$, and these views are supported

by the composition of the compound of gum with oxide of lead, as ascertained by BERZELIUS :—

	At. weight	Theory.	Centesimally.
1 Eq. Oxide of lead, { 1 Eq. Lead, 104 1 Eq. Oxygen, 8	112	39.58	38.25
1 Eq. Gum, { 12 Eqs. Carbon, 72 11 Eqs. Hydrogen, 11 11 Eqs. Oxygen, 88	171	60.42	61.75
1 Eq. Gummiæ of lead,	283	100.00	100.00

Fine gum-arabic consists almost entirely of *arabin*, the other constituents being the inorganic matter and moisture.

Pure arabin may be obtained by making a clear aqueous solution of gum, and adding alcohol, when the arabin is thrown down. It is an uncrystallizable amorphous solid, devoid of color, taste, or smell; soluble in water, whether cold or hot, but not taken up by ether or oils. It unites with alkalis. According to GUERIN, arabin consists of—

	Centesimally.
Carbon,	43.81
Hydrogen,	6.20
Oxygen,	49.85
Nitrogen,	0.14
	100.00

But it is clear that this analysis must be wrong, since gum itself contains no nitrogen, and no substances containing this element are required in the preparation of arabin. According to the same authority, gum-arabic contains 79.4 per cent. of arabin.

Uses.—Gum-arabic is employed in medicine as an emollient and demulcent, but more frequently as a vehicle for the exhibition of other medicines. It is sometimes slowly dissolved in the mouth to allay troublesome cough, and to diminish irritation of the fauces, by diluting the acid secretions, and sheathing the part from the action of the atmosphere. In inflammatory affections of the intestinal tube, as well as of the respiratory and urinary organs, gum is employed as a demulcent and emollient. A solution of gum may be used as a sheathing substance in cases of acrid poisoning; but its efficacy is believed to be owing to mechanical properties merely. In the state of powder, gum is occasionally employed to check hemorrhage from leech bites. As a vehicle for the administration of other medicines, it is used either in powder or mucilage—in the former condition to give bulk to active and heavy powders, as subchloride of mercury, tartrate of antimony and potassa, *et cetera*, and in the preparation of lozenges; in solution, to suspend insoluble powders—as oxide of zinc or musk—in water; or to diffuse oily and resinous substances through aqueous fluids, and to give form and tenacity to pills. Furthermore, adds PIKEIRA, it is exceedingly useful for various other pharmaceutical purposes, although it is now generally superseded by dextrin.

Its property of suspending fine powders or precipitates in solution, has caused its use in the manufacture of inks; and its clamminess when moist, and firmness when dry, have given rise to its application for cementing or pasting paper or other light articles which are not to be exposed to moisture.

ADULTERATION.—Gum-arabic, says NORMANDY, is

often adulterated with gum-senegal, which has almost the same appearance, and altogether the same qualities as the former; the latter being considerably cheaper, those pieces which are small, light-colored, dry, easily broken, and which, in fact, most resemble gum-arabic, are mixed with it, and sold as such.

It is sometimes also mixed with common cherry-tree gum; but this is generally in dark-brown irregular masses, difficult to break, and when thrown into water they swell and separate from the homogeneous mucilage afforded by the genuine gum in gelatinous clots. This is equally effective as a test, whether the gum is or is not pulverized.

Gum-arabic when ground is in the state of a white powder, and is consequently sophisticated with starch and flour, and the gum generally is altogether replaced by gum-senegal, or partly by cherry-tree gum.

Gum-senegal itself is often mixed, both when in tears and when ground, with cherry-tree gum.

The presence of starch and flour may be readily detected by boiling a small quantity of the suspected gum in water, and testing the mucilage, when it has become cold, with iodine, which imparts to starch an intense blue or violet hue.

PURIFICATION.—A patent was granted, in the year 1848, to M. H. PICCIOTTO, for two several methods of purifying and decoloring all varieties of gum-arabic. The first of these is as follows :—

A rather strong solution of pure sulphurous acid gas is prepared by one of the ordinary methods, and protected as much as possible from the contact of atmospheric air. In each six to twelve parts of this solution, one part by weight of gum, either in its natural state or in powder, is introduced. When it has dissolved, it will be found that the greater portion of its coloring matter will have been destroyed, or has chemically combined with the sulphurous acid, forming a colorless compound.

The sulphurous acid may be brought into contact with the gum by other methods than the one just described, as by passing a current of the gas into a concentrated solution of gum, or by introducing the gas into a close receiver, surrounded with a refrigerating substance or mixture; in which case, by the action of the cold and the pressure of the gas itself, it will be condensed into a fluid, and in this state may be commingled with a solution of gum.

Various processes may be resorted to for the removal from the solution of gum, of the free acid, or the acid combined with the coloring matter; but the patentee prefers the following :—

Heat is applied to the close vessel containing the menstruum, during which time the portion of gas evolved may pass through a tube into another receiver containing water, and thus be recovered for another operation. The hot mixture is then run off in small portions into a larger and open vessel, containing a slight excess of some salifiable base, which, in its combination with sulphurous acid, will form an insoluble salt. For this purpose, carbonate of baryta is to be preferred, as both the sulphite and sulphate of baryta are insoluble. The combination is aided by agitation, and when the whole of the disengaged car-

bonic acid gas has been driven off, and the solution has become neutral, it is allowed to rest for some hours—the vessel being covered—so that the coarser parts of the solid matter may be deposited. The neutralization of the acid may also be effected without previously heating the liquid; but then the patentee recommends that it should be heated after the combination has taken place, so that the whole of the carbonic acid, which might retain in solution a small portion of undecomposed carbonate of baryta, may be evolved.

The menstruum is now to be filtered, in order to remove the sulphite of baryta and other insoluble impurities. The filter employed by the patentee is a thin layer of pure gelatinous hydrate of alumina laid on cloth; but the liquid may also be forced through unglazed earthen or stone ware. After the solution has percolated either of these media, it will be found that all ligneous fibre, silicious and earthy matters, and all particles of insoluble gum have been separated and deposited on the vessels and filter employed, and very little color will remain in the depurated solution; but when a very white gum is required, the process of acidulation must be repeated. By evaporating the filtered menstruum, a colorless, tasteless, and pure gum is obtained, the natural properties of which have not been in the least degree altered.

The sulphurous acid gas may be separated from the solution of gum, without neutralizing it by means of a base, by boiling the mixture in a close air-tight, command and conducting the evolved gas into a receiver may taining water. If required, the bleaching proto be repeated, by introducing a current of pure or slight acid gas into the vessel containing the checked fermentation will by boiling of the solution to seventy degrees, cool, it will be found that an acid, originally united with the gum are deposited at the bottom of the vessel, and the pure solution may be drawn off; or the whole contents of the vessel may be emptied into cloth bags, when the fluid portion will percolate.

The second process is given underneath :—

The gum is dissolved in from six to fifteen parts of hot or cold water, and the solution filtered through cloth. A quantity of pure gelatinous hydrate of alumina is then thoroughly incorporated with the menstruum so as to form a thin homogeneous paste, and this being placed on cloth, a pure and greatly decolored liquid of gum will percolate. Instead of making the mixture just described, the simple solution of gum may be passed through a bed of alumina alone, or the latter with other substances; and, more time being allowed for the filtration, the decoloration will be quite as well effected. If a perfectly white gum is required, it will be essential that the process be again repeated; but as the second and third portions of alumina, after being used, contain very little tinctorial matter, they may serve again for the first decoloration of another quantity of gum. When the hydrate of alumina becomes highly tinged, it is washed with hot water on a filter, to separate the gum from it; after which it isedulcorated with a cold limpid solution of chlorine or chloride of calcium, filtered, and then repeatedly subjected to the action of a stream of hot water.

By these means, not only its original whiteness and purity, but also its chemical affinity for tinctorial matter, are restored.

STATISTICS.—Gum-arabic is imported either direct from Alexandria, Smyrna, Tripoli, Mogadore, Tangiers, *et cetera*; or second-hand from those places through Gibraltar, Malta, and the Italian ports.

Previously to the year 1842, the duty on gum-arabic from British colonies was six shillings per hundred-weight; from other parts twelve shillings; but the duty was then fixed at twelve shillings per hundred-weight upon all gums, of whatever origin, and this was subsequently reduced to one shilling upon the same quantity. Of twenty-five thousand, two hundred and eighty-nine hundredweight imported in 1839, Tripoli, Barbary, and Morocco furnished four thousand five hundred and eighty-seven; Turkey, four hundred and thirteen; and the Cape of Good Hope, two thousand seven hundred and thirteen, while fifteen thousand four hundred and thirty-one hundredweight were from the East Indies.

The trade in gum-senegal is principally in the hands of the French.

AUSTRALIAN GUM.—In 1848, Dr. HOPFF received a gum, purporting to be from Australia, which consisted of reddish-brown and brownish-yellow pieces, mostly semiglobular, translucent, with a greyish opalescence; parent, to which the bark was added, less decisive really this gum was much more mucilaginous than the opic, was easily pulverized, and gave a milky emulsion. A middle a slightly colored powder, obtained from the mountainous portions of India. In Bengal and the this gum to be identical with the gum of the same name. He had previously obtained in the warch, and the old drug firm subnitrate of mercury produced a *mil rubrum* astringent; nitrate of mercury gave a similar, named authority, action; chloride of mercury occasioned no change; iodine scarcely tinged the menstruum.—*Pharmaceutical Journal*.

From the above characteristics it will be seen, as Dr. PEREIRA has remarked, that the Australian gum bears more resemblance to that of the cherry-tree than that of the acacia.

GUM-BASSORA, though described by continental pharmacologists, seems to be new, of nearly so, in British commerce. According to Dr. PEREIRA, it occurs in variable-sized pieces, which are whitish or yellowish, and opaque. It appears to belong to the Bassorine class, as when put into water, it swells up, but dissolves only in part. Its origin is unknown.

BRITISH GUM.—*Artificial Gum*—*Torrefied Starch*—*Dextrin*.—Under these names a modification of starch is known, which is often prepared in the following manner:—

Well-dried starch is heated to 300° in sheet-iron trays, when it intumesces, giving off vapors and the odor of highly-baked bread, and forming yellowish-brown masses. This, when ground, is employed as a substitute for tragacanth, senegal, and similar gums, in the dressing, stiffening, glazing, sizing, dyeing, printing and finishing calicoes, nets, crapes, laces, silks, papers, and all goods of a similar kind.

Starch, when submitted to the above process, is converted into a gummy substance, which, having lost all gelatinous properties, is soluble in either cold or hot water; and iodine, instead of causing a blue color, as with unaltered starch, communicates to it a dingy purple tint.

It possesses the characteristic property of turning the plane of polarization to the right when acting on polarized light, and is consequently sold in Paris under the name of *dextrin*.

British gum or dextrin is now met with in commerce in three distinct forms; namely, as a white, brilliant, and pearly powder; as a sirupy solution; and in the form of exotic gum, in greater or less perfection, either broken into small fragments, or made into rolls of various sizes.

Formerly, it was only produced in the first condition, that of powder; and if some manufacturers have attempted to impart to it the appearance of the product for which it is so much substituted, they may have been induced to do so from the conviction, that the only way to supersede the old plan was by humoring and even deceiving its consumers with the outward appearance of the old product.

It has since been discovered, that many advantages, not primarily expected, are attendant on the communication to dextrin of the form and appearance of natural gum. It is easily dissolved, and makes a clear solution; in the state of powder it possesses the superiority over dextrin of being more readily packed; and over liquid gum, the advantage of not fermenting as an

A misapprehension seems to more frequently arise as a result of taking advantage of the fact that dextrin is more soluble in water than the other medicines. It is not, however, as soluble as the other medicines, and its use is attended with the same irritation of the stomach, by diluting the stomach with the same quantity of water, as the other medicines. It is not, however, as soluble as the other medicines, and its use is attended with the same irritation of the stomach, by diluting the stomach with the same quantity of water, as the other medicines.

British gum may be prepared by many other processes than the one just described. Besides being procured by torrefaction, it is also obtainable, either by the use of acids, or by means of diastase.

PAYEN discovered a method which furnishes a whiter and more soluble product than can be obtained by torrefaction. It consists in moistening one thousand parts of *dry* starch—potato-starch is generally used—with very dilute nitric acid, consisting of two parts of the concentrated acid to three hundred of water. The mass is then divided into small blocks, which, when exsiccated in the air, are rubbed down, and exposed in a proper stove to a current of air heated to about 150° or 160°. The powder is ultimately well dried at a temperature not exceeding 230°. When well made, it dissolves in cold or slightly warmed water, with the same facility as gum. The modified starch obtained by this mode has been also called *leicom*.—*Brande*.

A patent was granted in May, 1845, to J. F. PINEL, for improvements in the method of treating farinaceous matters for the production of British gum. The *modus operandi* is as follows:—

Half a gallon of nitric and half a pint of hydrochloric acid are mixed with one hundred gallons of spring water, and as much flour or fecula being then added as is sufficient to form a paste, the whole is well worked together, and left for two hours to settle. After the expiration of this time, the paste is carefully removed into buckets properly prepared for allowing the water to drain off. When this has been effected to the required extent, the mass is divided into small lumps, which are placed on shelves in a drying-room, and allowed to remain until fully desiccated. They are then reduced to powder, and placed on the shelves of a stove, the temperature of which is raised, on the first day to 100°; on the second to 150°; and on the third day to 190°. After this process, the powder is allowed to cool, and is then passed through a sieve. It is next placed in an oven, heated to from 300° to 350°, and when thoroughly baked it is ready for use.

The operator can ascertain if the process has been correctly carried out, by mixing a small quantity of the powder with filtered water, in which it should readily dissolve without leaving any sediment.

It will require little discrimination in the reader to see that this process, though there is some slight variation in the quantity and kind of acid, is yet essentially the same process with that of PAYEN given above.

If the flour or fecula be grey—that is, if it has been badly prepared, and adulterated or damaged—the A rather substitutes half a pint of sulphuric for the is preparative acid, by the agency of which, he states, lected as homogeneous matters are separated from the good spheric air.

one part by tent also extends to the production of the or in powder, is introduced, resemble natural gum both in be found in transparency; and for this purpose the powder is sifted, after it has gone through the stove and been sifted, with as much water as will bring it to the consistence of a paste, adding one part of nitric acid to each four hundred parts of water. When well mixed, the paste is spread upon copper dishes, in layers three-fourths of an inch deep, and subjected, in an oven, to a heat of 240° to 300°. As soon as it has become sufficiently hard, it is removed from the oven into the open air, and when cool, is ready for use.

Since the discovery, by PAYEN and PERROZ, of diastase—described at page 71, Vol. I.—another method for the fabrication of artificial gum has been devised.

This process seems to be the most worthy of attention, and by accepting the modifications of M. EMILE THOMAS, it will be found to give more perfect results than any other. THOMAS' improvements with the original method of operation are thus described in the *Bulletin de la Société d'Encouragement*:—

The fecula must be rendered soluble in vats, heated by steam in such a manner that the temperature can be lowered or heightened with ease. The fecula is first mixed with four times its weight of water, previously brought to the temperature of 120°; and, for this purpose, is gradually introduced into the boiler or other vessel containing the hot water. M. THOMAS employed double-bottomed copper boilers, capable of containing four hundred gallons, and at one operation, six hundred pounds of fecula, mixed with one thousand

two hundred quarts of water were decomposed. The temperature must be kept at about 140°, until the whole mass is converted into starch. Two per cent. by weight of very fine white malt, and the mucilage obtainable from one per cent. of linseed, are then added. The latter imparts tenacity to the gum. If a greater proportion of malt than that just mentioned were employed, the decomposition would, doubtless, be effected more rapidly; but much more glucose would be formed, and the gum would be, to a greater or less extent, colored.

The temperature of the mixture must be maintained at 120° or 140° until all the starch is redissolved, when it should be suddenly elevated to 167°, as nearly as possible, in order to cause the most powerful action of which the diastase is capable. The thorough agitation of the mixture is then requisite, until the decomposition is almost complete; this may be ascertained by the deep blue tint which the mixture acquires, and also by the action of iodine, which will communicate to the dextrin a purple or violet tint.

The operation lasts about an hour and a quarter; fifteen minutes are required for the formation of the paste, the same period for its dissolution, and the remaining time for rendering it soluble.

M. THOMAS prefers this method of forming the paste to adding the malt, as the reagent spreads much more uniformly throughout the mass, and does not subside to the bottom of the vessel.

The liquor must now be removed from the decomposing vats, and left in pans to settle. This may require from six to eighteen hours, according to the external temperature. During this period, a slight fermentation will be perceived, but it must be checked by the addition of one hundred and forty-five grains of alum for each twenty-five gallons of the liquid. It is essential that sufficient time be allowed for subsidence of the menstruum, as by this means two serious evils are avoided—the coloring of the gum during the baking; and a singular phenomenon so often observed in evaporating viscous liquids, namely, their being quite still, which, THOMAS states, is caused by the accumulation of a thick crust on the sides of the evaporating vessels.

The liquor, when drawn off after subsiding, is concentrated by raising it *very slowly* to the boiling point, which precaution is indispensable, for the perfect clarification is effected without any foreign agent, by the coagulation of the vegetal albumen contained in the malt and the linseed mucilage, and is best attained by checking the first boiling. The scum which rises while the heat is maintained, must be carefully removed, and if the boiling is too much accelerated, the gum will first become thick, and afterwards, will be colored. When a solid pellicle forms on the surface of the sirup, the baking will be completed.

If it be desirable to preserve the gum in a liquid form, the boiling must be stopped when the menstruum has acquired a sufficient density, and it must then be poured into well-closed vessels previously smeared with oil of turpentine, and the surface of the gum should be covered with a thin layer of the same. This method prevents, tolerably well, the fermentation of the fluid gum.

When the dextrin is to be solidified, the boiling sirup is poured into small, shallow tin vessels, placed upon a hot air stove, maintained at a temperature of from 100° to 120°. At the end of twenty-four hours the gum acquires the consistency of jujube paste, and it is then cut up, with a pair of shears, into small oblong pieces, which are rolled out upon a polished surface, with a wooden cylinder; dusted with pulverized artificial gum; and afterwards placed upon wooden frames, where it is allowed to remain drying for three or four days. THOMAS suggests that the gum would be much better desiccated by permitting it to run upon a cylinder heated to 230° or 250°, but he adds that the economy of this method is questionable.

The last-named authority has remarked with reference to British gum prepared by sulphuric acid, that it possesses the disadvantageous property of being deliquescent. This method is, therefore, never employed, as besides this, the products are often colored. He also states that when nitric acid is employed in the preparation of dextrin, *it must be perfectly pure*. Commercial nitric acid, as obtained by the action of oil of vitriol upon nitrate of soda, always contains a small amount of chlorine; and although this element is contained in diminished proportion in the dextrin, it is nevertheless sufficient to considerably lessen the brilliancy of the colors prepared with the dextrin. Several printers upon paper and vegetal tissues have observed this, but have been unable to account for it otherwise than by attributing it to the inferior quality of the gum.

GUM-BUTEA is the produce of the *Butea Frondosa*, a middling-sized tree, common in Bengal and the mountainous portions of India. DR. ROBERTS found this gum to be identical with *Gummi arabicum* which he had previously obtained in the warehoused drug firm in London, under the name of *Gummi rubrum astringens*. It occurs, according to the last-named authority, in small, elongated tears, which are blackish externally, and have fragments of bark adhering to them. Small fragments examined by transmitted light are ruby-red. It has an astringent taste, and contains from fifteen to twenty-five per cent. of impurities, consisting of wood, bark, small pebbles, and sand. According to SOLLY, the gum, when purified by water, so as to separate the extraneous matters, is composed of—

Centesimally	
Gum, with gallic acid and other soluble substances, ..	73.26
Tannic acid, ..	21.67
Soluble extractive, ..	5.07
100.00	

It is employed by the natives of North-western India for precipitating their indigo, and in tanning. English tanners, however, object to its use on account of the disagreeable color it communicates to the leather.

CHERRY-TREE GUM, *Gomme de cerisier*, French; *Kirschgummi*, German; *Gummi cerasi*, Latin; which is also procured from the trunks of plum, peach, apricot, and other rosaceous trees, is similar in appearance to the poorer qualities of gum-arabic. By the action of water, in which it is only soluble to a partial extent, it is divisible into two portions, that which is dissolved being *arabin*, while the insoluble matter is *cerasin*.

It has not been analysed, but its composition is probably the same with that of gum-arabic. Cherry-tree gum is not thrown down either by silicate of potassa or by nitrate of mercury. It does not gelatinise with sesquichloride of iron, but a precipitate is produced on the addition of chloride of tin.

It does not seem to have been employed for any purpose whatever in this country. Dr. PEREIRA has suggested its substitution for gum-tragacanth in medicine.

GUM-KINO.—*Gomme Kino*, French; *Gummi Kino*, German; *Gummi Kino*, Latin. Of this so-called gum there are two varieties, Botany Bay and East Indian kino, the former being the inspissated juice of the *Eucalyptus Resinifera*, or *Iron bark*, a native of Australia and Van Diemen's Land; while the latter kind is the produce of *Pterocarpus Erinaceus* or *P. Marsupium*. According to GRAY, when an incision is made in the trunk and branches of the tree, the juice exudes, at first, of an extremely pale-red color, and in a very liquid state; but it soon coagulates, becoming of a deep blood-red hue, and so remarkably brittle, that its collection is attended with some difficulty. East Indian kino, Dr. PEREIRA remarks, is presumed to be the substance referred to in the British pharmacopœias, as it is always regarded in commerce as *genuine gum-kino*. It is imported in boxes from Bombay or Tellicherry.

PROPERTIES.—East Indian kino occurs in small, angular, glistening fragments, the larger of which appear almost black; the smaller being ruddy. When entire, they are opaque, but in thin laminae are transparent and ruby-red. They are brittle between the fingers, soft in the mouth, adhere to the teeth, tinge the saliva roseous though inodorous also, and to water a deep-red color; the aqueous decoction, on cooling, becomes turbid. In the latter solution, gelatin, tartrate of antimony and potassa, acetate of lead, sesquichloride of iron, and nitrate of silver, produce precipitates.

Botany Bay kino is met with in irregular masses, many of them in the form of tears, somewhat resembling those of cherry-tree gum in outline, and as large as those of gum-senegal. The purer pieces are vitreous, almost black in the mass; but when in small and thin fragments, transparent, and of a beautiful ruby-red. Some of the pieces, however, from the intermixture of wood and other impurities, are dull. When chewed, it sticks to the teeth, and has an astringent taste, but is devoid of odor. Digested in cold water, it swells, becomes soft and gelatinous, and yields a red liquid, which gives an acid reaction with litmus paper, and yields precipitates with lime-water, gelatin, acetate of lead, sesquichloride of iron, and—if a little caustic potassa or ammonia be previously added—with chloride of calcium. Tartrate of antimony and potassa occasions no deposit. Digested in rectified spirit, Botany Bay kino becomes gelatinous, as with water, and affords a similar red solution, in which water causes no subsidence, but which reddens litmus, and deposits a copious precipitate when potassa, ammonia, or lime-water is added.—*Pereira*.

In 1852, Dr. CHRISTISON received from a merchant of Moulmein, a specimen of kino produced in that locality, possessing the physical and apparently the chemical properties of the ordinary kino. Though a small quantity of it was once shipped to England, it is yet, as an article of commerce, unknown.

The pharmacologist last named thus describes it:—

This product consists partly of little angular fragments; but there are larger masses which seem to be portions of cylinders, about half an inch in diameter, apparently moulded by collecting the juice in reeds. These have externally a greyish, striated surface, most unlike that of the broken fragments of commercial kino. They are easily frangible, the broken pieces possessing the exact appearance of ordinary kino, except that they are blacker and more glassy by reflected light; and though opaque, by transmitted light, when of very moderate thickness, yet in very thin fragments, they are of a splendid cherry-red color. They are easily reduced to fine powder, which has a dark, dirty, lake tint. Their taste is very slightly bitter, and intensely astringent.

Cold water acts more quickly on this kino than on that of commerce, gradually dissolving a very large proportion of it, forming a deep cherry-red astringent solution, and leaving a residue of greyish flocculent matter, which is soluble to a great extent in boiling water, and which appears to be analogous to the insoluble variety of gum called bassorin. Boiling water dissolves this kino almost entirely, and the menstruum, when cold, continues nearly transparent for at least an hour; it afterwards becomes slightly turbid, and a scanty flocculent precipitate slowly subsides. Both hot and cold solutions yield a copious precipitate of iron; when the menstruum is concentrated, a dirty-grey precipitate is formed so abundantly, that the whole fluid becomes a thick, pulpy mass. A solution of one part of the kino in twenty-five of boiling water forms, with the iron-test, a magma too thick to flow. Even a solution in seventy-five parts of cold water has a beautiful intense cherry-red color, and forms with sesquichloride of iron, in the course of an hour, a pulp so thick as to flow only sluggishly.

On comparing these characters with a fine specimen of kino of home trade, and also with a sample from the neighborhood of Goomsoor, Dr. CHRISTISON found the last two to be identical, with the single exception, that the Goomsoor product is somewhat redder when seen in bulk, and that the Moulmein kino is blacker, more vitreous in lustre, rather more easily soluble in cold water, and with rather less residue; and when the cold solution is diluted to the strength of one in seventy-five, it requires rather more sesquichloride of iron to throw down all its tannin, and, consequently, the precipitate forms with the water a somewhat firmer pulp. This kino dissolves, with only a trace of flaky residue, in rectified spirit, which forms an intense cherry-red tincture of very pure astringent taste. Its physical characters, the action of water, and the properties of the aqueous solution, are enough to prove that the Moulmein kino is identical with the kino of commerce, and, in point of quality, is somewhat superior. There is no

doubt, from its taste, and the action of the iron-test, that analysis will prove the presence of a larger proportion of tannin.

It does not absolutely follow, even from the exact coincidences now mentioned, that the Moulmein kino is derived from the same botanical source with the present official kino. The latter has been accurately referred, by the separate researches of GIBSON, PEREIRA, and ROYLE, to the *Pterocarpus marsupium* of ROXBURGH. But the *Butea frondosa* also yields a fine kino, which is scarcely distinguishable in chemical properties from the official kind.—*Pharmaceutical Journal*.

COMPOSITION.—Gum-kino was first analysed by VAUQUELIN, in whose days the resources of chemistry were very much limited, causing a deviation from the truth in many cases, and occasioning, with regard to all investigations of the period, a great amount of doubt as to their correctness.

The comparatively simple tabulation of VAUQUELIN's results is as under:—

	Centesimally.
Tannic acid and peculiar extractive,	75
Red gum,	24
Insoluble matter,	1
	100

The presence of catechuic acid has subsequently been proved by A. W. BUCHNER.

USES.—For medical purposes only; it is administered in cases of obstinate diarrhoea; it has occasionally been applied to flabby ulcers as a local astringent.

STATISTICS.—Gum-kino is imported from Rangoon and Madagascar into London and Liverpool, in chests and boxes containing each from one to three hundredweight. It varies in value from fifty to seventy shillings per hundredweight. Duty-free.

GUM-KUTEERA bears considerable resemblance to flaky tragacanth, for which it has occasionally been attempted to be substituted. GUIBOUT considered it as identical with gum-bassora, but PEREIRA states that it is very distinct. It is supposed to be produced by the *Sterculia Urens*, a plant of the family *Byttneriaceae*, and is unknown in British commerce.

GUM-MEZGNITE, known synonymously as *nuckeel*, *mezgneet*, or *musgnit*, has been described by MORFIT, who was led to submit it to a chemical examination, on account of the facility with which it may be obtained in large quantities, and its very probable prospective value as an article of commerce.

It is said to be the product of a tree flourishing extensively in the high and dry regions of the plains of Western Texas, New Mexico, and the adjacent Indian territory. It is a spontaneous semifluid exudation, concreting by exposure into tears and lumps of variable size and form. A portion of the sample obtained by Dr. SHUMARD—who first brought it into public notice in 1854—consisted of small irregular pieces and rounded balls about the size of a hazel-nut; semi-transparent, and shading in color from a lemon-white to a dark amber. When broken, the fractured surfaces were brilliant, and the gum was easily reduced to a dull white powder. One of the balls was enveloped with an outer pellicle of gum, about one-sixteenth of

an inch in thickness. Its specific gravity was 1.5, but MORFIT remarks that this determination may admit of correction upon purer samples than were obtainable.

Its proximate composition was found to be:—

	Centesimally.
Arabin,	84.967
Bassorin,	0.206
Water,	11.640
Inorganic matter,	3.000
Impurities,	0.236
	100.049

Its elementary composition is represented by MORFIT as—

	Centesimally.
Carbon,	44.706
Hydrogen,	6.500
Oxygen,	48.794
	100.000

which approaches very closely to that of gums arabic and senegal, as represented by GUERIN and MULDER. The general appearance of the gum, continues its describer, is similar to that of gum-senegal and the dark inferior qualities of gum-arabic; while in chemical properties it is also allied to them, being insoluble in absolute alcohol, partially soluble in alcohol of the ordinary strength, and readily forming with hot or cold water a very adhesive mucilage. It is, in fine, a true gum, and promises, in its physical and chemical behavior, much of the advantage expected by its discoverer, as an economical substitute for gum-arabic or senegal.

MUCILAGE.—*Mucilage*, French; *Schleim*, German; *Mucilago*, Latin.—Many seeds, roots, &c. when infused in water heated to 160° or 170°, impart to it a substance, which, when purified by percolation and evaporation, bears considerable resemblance to gum.

QUINCE MUCILAGE.—One part of quince seed, Dr. PEREIRA states, forms, with forty parts of water, a thick mucilage, which yields with acetate and subacetate of lead, protochloride of tin, nitrate of mercury, and sesquichloride of iron, gelatinous coagula or precipitates. Rectified spirit produces at first scarcely any effect; after some time partial concretion occurs. Sulphuric acid communicates a pinkish tint, and causes the separation of a frothy coagulum, which floats on the mixture. Silicate of potassa, infusion of galls, and oxalate of ammonia produce no change in the mucilage. Quince mucilage is distinguished from arabin, by the effect on it of alcohol, silicate of potassa, oxalate of ammonia, and sulphuric acid; from bassorin and cerasin by its solubility, both in cold and hot water; from tragacanthin, by the reactions caused by alcohol, oxalate of ammonia, and sulphate of iron; from *carrageenin*—see carrageen mucilage below—by the effect of silicate of potassa and acetate of lead. From these and other peculiarities, Dr. PEREIRA proposed to call it *cydonin*—derived from the name of the quince-tree, *Cydonia Vulgaris*.

CARRAGEEN MUCILAGE.—The mucilaginous constituent of Carrageen or Irish moss—*chondrus crispus*—termed by some writers vegetal jelly, or vegetal mucilage, was, from its appearing to have peculiar characteristics, designated by Dr. PEREIRA *carrageenin*. Its

properties, according to that distinguished pharmacologist, are as follow :—

Carrageenin is soluble in boiling water; the menstruum gives precipitates with subacetate of lead and silicate of potassa, and, if sufficiently concentrated, gelatinizes on cooling. It is distinguished from ordinary gum by its aqueous solution not producing a precipitate on the addition of alcohol; from starch by its not assuming a blue color on the addition of iodine; from animal jelly by tincture of galls producing no precipitate; from pectin by the absence of any reaction with acetate of lead, as also by the formation of no mucic acid on the addition of nitric acid.—*Pereira's Materia Medica.*

LINSEED MUCILAGE is extracted from the seeds of the flax-plant, *Linum Usitatissimum*, by the agency of hot water. Alcohol causes the formation in it of white mucilaginous flocks. It is also precipitated by protochloride of tin, and by acetate and subacetate of lead. It possesses an acid reaction, and is not changed by chlorine or iodine. On evaporation, a substance similar in appearance to gum-arabic is obtained, which, when digested in water, intumescs, and partially dissolves.

There are many other mucilages, but as they possess characters in common with those described, a notice of them would be unwarrantable.

GUM-TRAGACANTH, or *Gum-dragon*—*Gomme tragacante*, French; *Gummi tragant*, German; *Gummi tragacantha*, Latin—is a natural exudation from different varieties of the *Astragalus*, or milk-vetch. OLIVIER states that the tragacanth of Asia Minor, Armenia, and northern Persia, is yielded by the *A. Verus*. Mr. BRANT, English consul at Erzeroum, forwarded to Dr. LINDLEY a specimen of *A. Gummifer*, which was stated to be the tragacanth plant of Koordistan, and producing the white or best kind of gum. It was accompanied with a plant of *A. Strobiliferus*, which was said by the same authority to be the shrub from which the red or inferior species of tragacanth is produced.

According to TOURNEFORT, the *Astragalus Creticus* also yields the gum.

DESCRIPTION.—Gum-tragacanth is white, yellowish, or yellowish-brown, and occurs either in moderately large, broad, thin pieces, marked with arched or concentric elevations—*fluky tragacanth*,—or in small, twisted, filiform, spiral fragments—*vermiform tragacanth*. The former is the kind usually found in this country, while the latter is common on the Continent.

COLLECTION AND ASSORTMENT.—According to S. H. MALTASS, the following is the manner in which gum-tragacanth is collected :—In July and August the peasants clear away the earth from the lower part of the shrub, and make several longitudinal incisions in the bark; the gum exudes the whole length of the incision, and dries in flakes; three or four days are sufficient for this purpose, and the product is then collected. In some places the peasants also puncture the bark with the point of the knife. If the weather be hot and dry, the gum is white and clean; but if the atmosphere be damp, and the temperature but moderate, a longer time is required for inspissation, and the gum assumes a yellow or brownish tinge.

High winds are favorable for drying, but they cause the contamination of the gum with earthy and silicious matters. While engaged in this labor, the peasants pick off from the shrubs the gum which exudes naturally, and this constitutes the variety known in Britain as *common* or *sorts*. The whole of the tragacanth gathered is mixed and sold to native merchants, who send it to Smyrna for re-sale, in bags containing about two hundredweight each. In this state it is termed *rough gum*, and contains as follows :—

	Per Cent
Flaky or leaf gum, perfectly white, . . .	40 to 50
Flaky or leaf gum, discolored or brown, . . .	15 to 25
Vermicelli gum,	10 to 15
Common or sorts,	35 to 10

The finest parcels, continues this authority, contain the most *vermicelli*, which is nothing more than the siftings of the *leaf* gum which is broken by carriage from the interior, and by removing from one place to another, together with the small vermicular masses termed *Sesame seed*, which are collected with the leaf gum.

When gum-tragacanth is purchased for shipment to Europe, it undergoes the following assortment :—The large, white, flaky, or leaf gum, termed *French quality*, is first picked out, and the residue is sifted. The coarser portion is returned to the pickers, who remove the *discolored leaf*, which is termed *English quality*. The remainder is then examined, and any stones, or dirty, very black pieces are thrown aside as refuse; the rest, composed of naturally exuded gum and brown leaf, is denominated *common* or *sorts*.

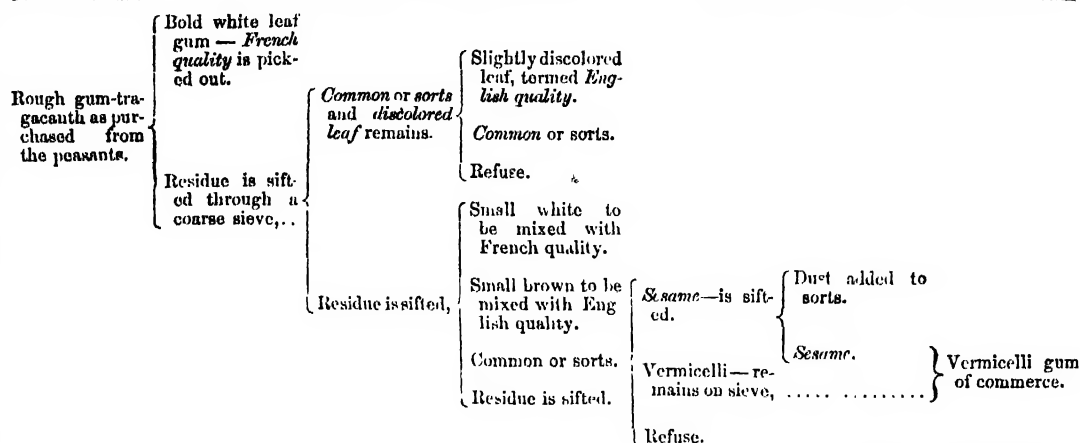
The head-man or master-picker then subjects the gum which passed through the first sieve, to the action of a second and finer one, occasionally throwing out any straw or other light extraneous substance which may rest at the top. The gum remaining after this second sifting is given to the women to assort at their own houses. The *white* is separated from the *brown*, and the latter from the *common*. The first is mixed with the French, the second with the English quality.

A third, and still finer sifting now takes place. The gum which passes through is termed *Sesame seed*; the coarse, which remains upon the sieve, is *vermicelli*. Both qualities are carefully picked by women. When cleaned, the *Sesame seed* is again sifted, and the dust and minute particles are added to the *sorts* or *common* gum. The *Vermicelli* and *Sesame seed* are then commingled, forming the *vermicelli tragacanth* of commerce.

When the gums are intended for the French market, the fine white leaf only is shipped; the *vermicelli* is sold for Trieste, and the discolored leaf and *sorts* for England.

If, however, the whole parcel be worked for Britain, and be required *good*, the French and English qualities are mixed, and the brown leaf which had been left in the *sorts* is also picked out and added. This procedure reduces the value of the *common* or *sorts*.

The various siftings and pickings to which gum-tragacanth is subjected at Smyrna, may be thus tabulated :—



—*Pharmaceutical Journal.*

PROPERTIES AND COMPOSITION.—Gun-tragacanth is the type of the *Bassorin* class of gums. It is destitute both of taste and odor. Its toughness is so great as to prevent its pulverization until it has been exsiccated at 212°, when it becomes tolerably brittle. Instead of dissolving in water like gum-arabic, it intumesces, forming a mucilaginous magna. On subjecting this to ebullition with water, it gradually acquires the appearance of a solution of gum-arabic, in consequence, **BRANDE** supposes, of its transmutation into arabi.

The soluble portion of gum tragacanth—tragacanthin or adragantin—is generally regarded as identical with gum-arabic, but differs from it in being unchanged by sesquichloride of iron, or silicate of potassa, and also by the flocculency of the precipitate occasioned by alcohol. Subacetate of lead, protochloride of tin, and protonitrate of mercury, produce deposits similar to those caused in a solution of gum-arabic. The presence of lime is shown by the subsidence occasioned by oxalate of ammonia.

The insoluble part of gum-tragacanth—*bassorin*—is similar to that of gum-bassora. Starch globules may be seen in it, with the aid of a good microscope, and the blue coloration produced in it by iodine is a proof of the presence in it of that principle.

DE CANDOLLE has suggested that the intumescence of tragacanth may be caused by the gummy matter being enclosed in cells.

GUINBOURT states that neither arabin nor bassorin are present in gum-tragacanth, but that it is composed of an organised gelatiniform matter, very diverse, both chemically and physically, from gum-arabic, and which swells and divides in water, so as partially to traverse a filter. The same chemist considers the insoluble portion of tragacanth to be a compound of starch and lignin, and to have, in no respect, the same properties with bassorin.

GUERIN-VARRY estimated the proximate principles of tragacanth as under:—

	Centennially.
Tragacanthin or arabin,.....	53·3
Isoscorin and starch,.....	33·1
Water,.....	11·1
Inorganic matter,.....	2·5
	<hr/> 100·0

The ultimate constituents of gum-tragacanth have been determined by HERMANN, and by GUERIN-VARRY:—

	At weight	Centesimally represented.	
		Theory.	Hermann.
10 Eqs. Carbon,	60	40.00	40.50
10 Eqs. Hydrogen,	10	6.66	6.61
10 Eqs. Oxygen,	80	53.31	52.89
1 Eq. Gum-tragacanth,	150	100.00	100.00

GUERIN-VARRY'S results are as follow:—

	Centesimally.	
	Soluble part	Insoluble part
Carbon,	42.01	35.79
Hydrogen,	6.42	7.11
Oxygen,	54.47	57.10
	<hr/> 102.90	<hr/> 100.00

Uses.—Gum-tragacanth is occasionally employed in medicine as a sheathing or demulcent agent in irritation of the mucous membranes; and also as a vehicle for the administration of active and heavy medicines.

Shoemakers use the inferior varieties, in the form of mucilage, for imparting a gloss to the heels of boots.

ADULTERATION.—According to S. H. MALTASS, gum-tragacanth is adulterated with two inferior gums. These, he says, are collected in Armenia and Caramania from various trees, principally wild almond and plum. That from the former locality is sent to Constantinople from Moussul, whence it takes the name of *Moussouli*. The Caramanian product is sent direct to Smyrna, and is termed *Caraman*.

Both these gums, continues he, are almost worthless, but fetch high prices for the purpose of mixing with gum-tragacanth. By some they are considered to be an inferior kind of the same gum. As neither Caramania nor Moussul gum occurs in flat pieces like tragacanth, and as they are of a dark color—particularly the former—they would be easily detected if mixed with leaf gum without previous preparation. The Jews, therefore, who adulterate all the drugs of Turkey, have found means of deceiving the eye by breaking up the spurious article into small irregular pieces, which are then coated with *white-lead*. The leaf gum is sophisticated with this at the rate of fifty

per cent. For mixing with the Vermicelli gum, the adulterant is broken into smaller fragments, and added only to the extent of twenty-five to thirty per cent. The pieces are left largest for the sorts or common gum, which often receives even a hundred per cent. of this vile trash.—*Pharmaceutical Journal*.

When pulverized, gum-tragacanth is very often mixed with a multitude of other cheaper powders, more especially with gum-senegal.

A mixture of gums tragacanth and senegal always forms with water a thinner mucilage than the same quantity of either of them alone. The following process is indicated by PLANCHE for the detection of this fraud:—Make a mucilage of the suspected gum, and add to it a few drops of alcoholic tincture of guaiacum, taking care to agitate the menstruum all the while. If the gum under examination contain any gum-arabic, the mixture, in the course of a few minutes, assumes a fine blue color, whilst if the gum-tragacanth be pure, the tint is unaltered. One-twentieth of gum-arabic can thus be detected. It should be remarked, that only

four or five drops of tincture of guaiacum should be employed for two drachms of mucilage, and that when the quantity of gum-arabic is very small, three or four hours must often elapse before the change of color can be observed. When rectified alcohol is poured in a clear and filtered mucilage of gum-tragacanth, it produces only a few flakes, which float in the menstruum, but do not impair its transparency; whilst, if gum-arabic be present, either a precipitate occurs in the liquid, or it becomes opalescent, according to the proportion of gum-arabic which it contains.—*Normandy*.

STATISTICS.—Gum-tragacanth is imported in cases of one hundredweight each into London and Liverpool. Its value, picked, is from ten to fourteen pounds sterling per hundredweight; sorts, from four to eight shillings per pound. Duty-free.—*Poole*.

Subjoined are particulars of the imports and exports of gums—Arabic, Senegal, Kino, and Tragacanth, those being the only gums noticed in the Returns of the Board of Trade—during the years mentioned:—

IMPORTS.						
	1850.	1851.	1852.	1853.	1854.	1855.
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
Gum-arabic,	41,949	46,032	48,484	61,614	40,456	43,960
Gum-senegal,	2,035	2,738	4,267	6,150	3,171	2,164
Gum-kino,	107	435	159	101	3,215	611
Gum-tragacanth,	526	791	1,151	1,390	582	300

EXPORTS.						
	1850.	1851.	1852.	1853.	1854.	1855.
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
Gum-arabic,	14,425	10,025	12,265	14,559	12,517	20,607
Gum-senegal,	5	—	39	80	93	388
Gum-kino,	118	46	169	91	473	22
Gum-tragacanth,	128	109	167	296	123	131

GUM-RESINS.—*Gommes-résines*, French; *Schleimharze*, German; *Gummi-resina*, Latin.—This class of vegetal products has long been recognised in pharmacy, and the various substances forming it certainly possess a sufficient number of peculiar properties to entitle them to be ranked apart. Their nature is not expressed by the term *gum-resin*, and the designation has consequently been condemned as improper; but it has been long sanctioned by use, and seems likely to be retained. They are the inspissated juices which exude either spontaneously, or by means of incisions, from the stems, branches, and roots of certain plants; and consist of resin, gum, essential oil, with other vegetal substances, as starch, and a small amount of inorganic matter. Their general properties are, that they are solid, most commonly brittle, usually opaque, or at least their translucence is not so great as that of the resins; they have almost always a strong smell, and often an acrid taste. Water partially dissolves them, but the resulting menstruum is opaque, and in general, lacteous. Alcohol takes up a portion of them, forming a transparent solution, which is rendered milky by the addition of water. They are principally used in medicine, having little application in the arts and manufactures.

AMMONIAC.—*Gomme Ammoniaque*, French; *Ammoniak-gummi*, German; *Ammoniacum*, Latin.—This substance is the product of the *Dorema Ammoniacum*,

a glaucous green plant, about seven feet high, the stem being about four inches in circumference at the base; a native of Persia. The whole plant, according to PEREIRA, is abundantly pervaded with a milky juice, which exudes upon the slightest puncture being made even at the ends of the leaves. This sap, when hardened, is the commercial ammoniac or ammoniacum of the present day.

The last-named authority states that this term has also been applied to a gum-resin, the produce of the *Ferula Tingitana*, which constitutes the ammoniacum of HIPPOCRATES, DIOSCORIDES, and PLINY. The second of these writers says, that ammoniacum is obtained from a species of *Ferula*, growing near Cyrene, in Africa. PLINY terms the plant Metopion, and states that it grows in that part of Africa which is subject to Ethiopia, near the temple of JUPITER AMMON, and received its name, as also did the gum-resin which it produced, from a Greek word signifying *sand*, in allusion to the arenaceous nature of the soil of the country. Two kinds of ammoniac are mentioned both by DIOSCORIDES and PLINY; the best resembled olibanum, and had a bitter taste, and an odor like castoreum; the commonest had a resinous appearance, and was commingled with earth and stones. Dr. LINDLEY assured Dr. PEREIRA, that African ammoniac was certainly the produce of *Ferula Tingitana*.

As the Greeks and Romans made no mention of

Persian ammoniac, the product of the Dorema Ammoniacum, they were, probably, unacquainted with it. AVICENNA notices ammoniac, but says nothing of its origin. That of ABU MANSUR MOWAFIK, a Persian physician who wrote about A.D. 1055, and of BEVA BEN KHYAS KHAN, A.D. 1512, was, doubtless, of the Persian kind. The Arabic terms by which the three last-mentioned authors designate ammoniac, resemble the name by which the plant is now known in Persia; hence it may be concluded that they all referred to the same object.—*Pereira*.

DESCRIPTION AND PROPERTIES.—Ammoniac is found in tears and drops, sometimes distinct, but more generally in agglutinated masses. Externally the tears are yellow, with a tinge of brown, with a waxy lustre; internally they are white or cream-colored, and opaque. It is moderately hard, and at ordinary temperatures brittle, but softens like wax with the heat of the hand. It has a faint and somewhat unpleasant, but very peculiar odor, best detected by subjecting it to heat; its taste is bitter and nauseous.

M. PICARD, in 1852, discovered by accident a very characteristic reaction of chloroxide of sodium—usually known as hypochlorite of soda—upon gum-ammoniacum. The addition of a few drops of a solution of the former to an alcoholic menstruum containing ammoniacum dissolved, causes the immediate development of a very distinct coloration. As this chemist was operating at the time with the commercial alkaline salt, which consists not only of chloroxide, but also of chloride of sodium and carbonate of soda, he thought it proper to inquire which of these compounds caused the reaction, and he soon found that it was due wholly to the chloroxide. Another question presented itself:—Is it the resinous or the gummy part of the ammoniacum which acts in this phenomenon? To find an answer to this, he attempted the complete separation of the two principles by the following method:—An alcoholic solution of ammoniacum, evaporated to the consistence of a sirup, was precipitated by distilled water. The resulting resin, well edulcorated, was redissolved in alcohol, evaporated, and reprecipitated. This treatment was repeated until nothing more was removed by the water, when the resin might be considered as pure. Its alcoholic solution behaved with chloroxide of sodium, like the gum-resin from which it was derived.

The evaporated menstruum obtained in isolating the resin was treated with alcohol, which precipitated the gum, and this manipulation was successively repeated until the gum, which had a brownish cast, dissolved easily and completely in water. This menstruum giving no reaction whatever with the chloroxide, warranted PICARD in asserting that the coloration was due exclusively to the resin. To attain to more precision, he acted on the method prescribed by PELLETIER and BONASTRE for the separation of the resins, which, since their researches, have been termed *resins* and *sub-resins*, according to their solubility in ether; and found that the ethereal solution, which was of a fine amber tint, at once gave the reaction with the alkaline chloroxide; while the small blackish globule of insoluble matter, when affused with ether and dis-

solved in alcohol, was unaltered by the reagent in question.

The sensibility of the reaction of chloroxide of sodium upon ammoniacum is very intense; a mere trace of the former in a menstruum containing the latter is sufficient to produce the phenomenon. This coloration, however, is not persistent; it disappears in contact with the air. If but little chloroxide has produced the reaction, it will reappear on a further addition; but if the reagent be in excess, the presence of another quantity will not induce a return of the tint. A large excess of chloroxide causes it to vanish, especially with the addition of an acid which disengages chlorine. To study the reaction satisfactorily, PICARD proposes three questions:—

1. Of all the resins and gum-resins, is ammoniacum the only one which thus comports itself with chloroxide of sodium, so that this reaction would serve as a distinctive characteristic of it?

2. Is this reaction peculiar to the chloroxides, and have the oxidising agents which most nearly resemble them no analogous result?

3. Is it possible by means of this reagent to detect gum ammoniacum in a pharmaceutical preparation, when it is mixed with other substances?

There are so many characters, continues the distinguished French pharmacologist, common to all resins, that gum-ammoniacum could scarcely be expected to possess exclusively the property of being influenced by chloroxide of sodium. If the resin of guaiacum, however, be excepted, which gives with this reagent a bluish-green coloration, none were influenced. The principles furnished by vegetables of the same family offer a remarkable analogy of chemical and therapeutical properties. Galbanum, sagapenum, opoponax, asafoetida, furnished by the *Umbelliferae*, a natural family from one of the species of which gum-ammoniacum proceeds, have, however, shown no change when treated with chloroxide of sodium. It is the same with myrrh, olibanum, mastic, sandarac, resins of jalap, scammony and elemi, liquid and calamite storax, benzoin, balsam of tolu, dragon's blood, euphorbium, colophony, resin pitch, white pitch, and turpentine. A distinctive characteristic of gum-ammoniacum is, therefore, its property of assuming a red color with chloroxide of sodium. It should, however, be mentioned that these experiments were made with the alcoholic tinctures, and not with the isolated resins.

The chloroxides of potassium and calcium have the property, in common with that of sodium, of developing the tint; but chlorine does not possess it. If a little carbonate of soda is previously added to chlorine water, the coloration is readily effected, in consequence of the formation of a small amount of chloroxide. Chloric, iodic, chromic, nitrous and nitric acids, and sesquichloride of iron, offer nothing remarkable.

In these investigations, the very powerful vinous color communicated to aloes by the alkalies must be borne in mind. Chloroxide of sodium from its alkalinity, reacts in a similar manner.—*The Chemist*.

A specimen of African ammoniac sent from Tangiers in 1839, is thus described by Dr. PEREIRA, to whom it was presented by Dr. LINDLEY:—It is an oblong

piece, about three inches long, and one and a half inch thick and broad. Its weight is about eight hundred and thirty grains. Externally it is irregular and uneven, and has a dirty appearance, similar to that which ammoniac would present after repeated handling and long exposure to the air in a dusty situation. It is partially covered with paper. A few pieces of reddish chalky earth, effervescing with acids, are found adhering to it, though the proportion of this on the specimen in question is not sufficient to affect in any way its saleability. It appears to be made up like Persian ammoniac, of agglutinated tears; the internal appearance is also much the same as that of the ordinary gum-resin, except that it is not so white, having a brownish, reddish, and in some places a faint bluish hue. Its odor is very faint, and when it is heated, obviously very distinct from that of Persian ammoniac. Its taste is also much slighter.

COMPOSITION.—Ammoniacum has been analysed by several chemists, with various results. BRACONNOT found it to yield the following:—

	Centesimally
Resin,	70.0
Gum,	18.4
Gluteniform matter, insoluble in water and alcohol,	4.4
Water,	6.0
Loss,	1.2
	100.0

HAGEN's analysis gave:—

	Centesimally
Resin,	68.6
Gum,	19.3
Gluten,	5.4
Extractive,	1.6
Silicious matter,	2.3
Volatile oil and water,	2.8
	100.0

But these statements of the composition of ammoniacum, from the limited means of analysing organic substances at the time they were deduced, are very unsatisfactory; and there is no doubt that an investigation of the subject, now that organic chemistry has become so fully developed, would show their erroneousess. Of the volatile oil of ammoniacum, little, indeed nothing, is known; Dr. PEREIRA giving as a description of it, the simple statement that it is transparent and lighter than water.

JOHNSTON obtained the resin of ammoniacum by digesting the gum-resin in alcohol, whereby he obtained a pale yellow solution, which, on evaporation at 150°, gave a transparent, nearly colorless resin, having the characteristic odor of the natural product. This resin is soluble in alcohol and the alkalies; partially so in ether, and in fixed and volatile oils. Heated to 212° for some time, it assumes a yellow color, which gradually deepens, while at the same time the peculiar odor becomes less intense. It is easily fusible, and decomposes at a continued heat of 270°; the volatile matter which is evolved containing more oxygen in proportion to the hydrogen than exists in the resin itself. JOHNSTON has expressed its composition, after slow but complete desiccation, by the formula, $C_{40}H_{28}O_9$.

USES.—Ammoniacum is principally employed in medicine; internally, its chief, almost sole use, is in chronic pulmonary affections, and even in these cases, it is unsuitable if there be irritation or inflammation of the bronchial membrane. Externally, it is applied in the form of plaster to glandular enlargements and indolent affections of the joints, as a discutient or resolvent.—*Pereira*.

Its only use in the arts, says URE, is in the formation of a cement for joining broken china and glass, and which is prepared as follows:—Take isinglass, one ounce; distilled water, six ounces; boil these together down to three ounces; add half that quantity of strong alcohol, seethe the mixture for two or three minutes, and then strain it; next add, while hot, first, half an ounce of milky emulsion of ammoniacum, and then five drachms of an alcoholic solution of resin mastic. This resembles an article sold as diamond cement.

ASAFOETIDA—*Asa fetida*, French; *Asafetida*, *Teufelsdrück*, German; *Asafetida*, Latin—is obtained from the *Ferula Asafetida*, an umbelliferous plant found in Afghanistan, Saristan, and the Punjab. The footstalks of the leaves, and the fibres of the root, being previously removed, incisions are made in the latter, and the gum-resin then exudes, and is removed. This procedure commences about the middle of April, and is repeated towards the latter end of May, and the beginning of June and July in each year.

According to Dr. PEREIRA, the root of the *Ferula Asafetida* is perennial, tapering, ponderous, increasing to the size of a man's arm or leg, covered with a blackish-colored bark, and beset near the top with many strong rigid fibres; its internal substance is white, fleshy, abounding with a thick milky juice, which has an excessively strong, fetid, alliaceous odor. The stem is two or three yards high, six or seven inches in circumference at the base, and smooth. The radical leaves attain the length of nearly two feet, and have been compared by KÄMPFER as resembling in shape those of the pæony, but in color and other respects those of common lovage. The fruit is flat, thin, reddish-brown, like that of parsnip, but rather larger and darker.

This is now considered, continues the last-named authority, to be the genuine asafetida plant; but there is reason to believe that a gum-resin like asafetida has been procured from other species of ferula. *Ferula Persica* has been described by Dr. POPE as the true asafetida plant, and the Edinburgh College of Physicians admitted it as being probably one source of the gum-resin. That it really does yield asafetida seems likely, moreover, from the strong odor of the drug which pervades the entire plant.—*Pereira*.

HISTORICAL NOTICE.—For the historical notice of asafetida, the Editor is also indebted to Dr. PEREIRA, who has collected from many sources the following:—It is uncertain at what period asafetida was first known or described. The difficulty in determining its history arises from the confusion which has existed with respect to the *Succus Cyrenæicus* and asafetida. By many writers the two substances were considered to be identical; but this opinion seems now to have been satisfactorily disproved by the discovery of the plant

which yields the Cyrenaic juice, and which agrees tolerably well with the rude figures struck on the Cyrenian coins. It would appear, however, that the Cyrenaic juice becoming scarce, the ancients employed some other substance of similar, though inferior, properties as a substitute, and to both of these they applied the term *laser*. For many years, says PLINY, this plant has not been found in Cyrenaica, because the publicans—or farmers of the taxes—who rent the pastures, finding it more profitable, destroy it as food for cattle. One stalk only, found in these days, was sent to the Emperor NERO. It may be known when cattle meet with young shoots of it, by the sleeping of the sheep, and the sneezing of the goats, when they have eaten of it. For a long time past the only laser brought is that which is produced abundantly in Persia, Media, and America, but it is far inferior to the Cyrenaic. It is not at all improbable, continues Dr. PEREIRA, that the laser of Persia may have been the asafetida of the present day. MURRAY says the word *asafetida* seems to have been introduced by the monks into the school of Salernum. But it appears to have been of oriental origin, and may be, as some have suspected, derived from the word *laser*. There are two kinds of *assa*, says AVICENNA, one *fetid*, the other *odoriferous*.—*Materia Medica*.

DESCRIPTION.—Asafetida is found in irregular yellowish or pinkish-brown fragments, of different sizes. The newly-fractured surface is whitish or cream-colored, semi-transparent, and possesses a waxy lustre; but on being subjected for a few hours to the combined influence of air and light, it becomes violet-red, and after the lapse of some days, yellowish or pinkish-brown. Dr. PEREIRA has described three varieties:—

1. *Asafetida in the tear*, which occurs in distinct, roundish, flattened, or oval drops, and also in irregular pieces, varying from the size of a pea to that of a walnut, of a yellow or brownish-yellow externally, but white internally. It is not at all improbable that this variety is obtained from a source different from that whence the lump asafetida is procured; for its color, externally, is more yellow, its odor is much feebler, and its freshly-fractured surface becomes more slowly and less intensely red by exposure to the atmosphere. As it has considerable resemblance to *ammoniacum in the tear*—with which, indeed, except by its odor, it might readily be confounded—may it not be the substance which OLIVIER calls ammoniacum, and which, he says, is produced by *Ferula Persica*?

2. *Lump asafetida*, which is the variety usually found in the shops. It occurs in variable-sized masses, of irregular forms, and having a reddish or brownish-yellow tinge. Frequently these masses are observed to be made up of tears, agglutinated by a reddish-brown substance; these form that kind of asafetida sometimes designated *amygdaloid*.

3. *Stony asafetida*. Dr. PEREIRA never met with this in English commerce, but has described samples which he received from Dr. MARTINY: It occurs in irregular, more or less angular, pieces, which have the odor of asafetida, and a yellowish-brown color, and present numerous small shining points or plates. It slightly effervesces in hydrochloric acid. By incine-

ration it yields a white ash, which strongly effervesces on the addition of acids. ANGELINI found in stony asafetida 51.9 per cent. of sulphate of lime.—Dr. Pereira.

PROPERTIES AND COMPOSITION.—Asafetida is very easily known by its peculiar alliaceous odor. This is the more readily appreciable when the gum-resin is subjected to heat. Exposed to light and air, its recently broken surface soon acquires a red color, which gradually passes into yellowish or pinkish-brown. Its taste is acrid and bitter. With sulphuric acid and heat it blackens; a dark, blood-red fluid is produced, and sulphurous acid is evolved. On diluting the menstruum, and adding an excess of caustic potassa, a beautiful blue color may be seen by reflected light, more especially on the surface.

Asafetida consists principally of resin, gum, and volatile oil. BRANDES analysed it with the following results:—

	Centesimally
Resin,.....	48.5
Gum, with traces of saline matters, . . .	19.0
Bassorin,.....	6.4
Volatile oil,.....	4.5
Extractive, with saline matters,.....	1.4
Sulphate and carbonate of lime,.....	9.3
Oxide of iron and alumina,.....	0.4
Sand and lignin,.....	4.5
Water,.....	6.0
	100.0

The volatile oil of asafetida is prepared by distillation, either with water or alcohol, and passes over colorless, though by a brief exposure to the atmosphere it becomes yellow. It possesses first a mild, and subsequently a bitter taste; its odor is remarkably powerful, and as it is very volatile, the atmosphere of any apartment where it may be exposed is soon impregnated with it. It is very soluble in alcohol and ether, but two thousand times its weight of water are required to dissolve it. It contains sulphur, which may be known by its blackening silver, and Dr. PEREIRA thinks it probable that phosphorus is likewise present. According to some, the oil is composed of two sulphides of the hydrocarbon, $C_{12}H_{11}$, and when freshly distilled, like the essential oils of black mustard and horse-radish, it contains no oxygen. It acquires an acid reaction from continued contact with the air, and on boiling it, sulphide of hydrogen is disengaged.

The resinous matter of asafetida may be isolated by digesting the gum-resin in alcohol, and evaporating the solution; by this simple process, however, it cannot be considered as pure, and it is better obtained in this state by adopting the method described by M. PICARD for the preparation of the resin of ammoniacum, and given at page 321. It is soluble in alcohol, oil of turpentine, and oil of almonds. It has the characteristic odor of the gum-resin, and the property which the natural product possesses of becoming violet-red by exposure to the sun's rays. BRANDES states that ether divides it into two portions, resin and sub-resin, which he has described²; but JOHNSTON affirms that it is *readily and completely soluble in ether*. Like many other resins, it must be heated for a length of time before it becomes hard and brittle, and reaches its normal condition.

By this prolonged heating, it acquires a darker and brownish color, and is easily decomposed if the heat be carried much beyond 212°. As the temperature rises, the resin froths up very much for some time, giving off a strong alliaceous odor; it then flows quietly till the heat is again increased.

Its elementary composition, according to JOHNSTON, is represented by the formula, $C_{40}H_{28}O_{10}$, which differs from that of the resin of ammoniacum in containing the elements of an additional equivalent of water.

USES.—In Europe solely as a medical agent; it is found highly useful in spasmodic or convulsive diseases not dependent on the nervous centres; as a stimulating expectorant and antispasmodic in chronic catarrh; in affections of the alimentary canal; as an emmenagogue in uterine obstructions. In some oriental nations, as mentioned in the historical notice of asafetida, it is employed as a condiment.

BDELLIUM.—By this term two gum-resins are understood; one, obtained from *Amyris Commiphora*, the bdellium of Holy Writ, known as *Indian bdellium*, or *false myrrh*; the other, derived from *Heudolitia Africana*, is called *African bdellium*. It is called by the natives, *niotout*. It occurs in commerce in translucent tears, often of considerable size. These vary in tint, some of them being of a brown color, more or less dark. By age they become opaque, and covered with a white or yellowish dust. Their fracture is dull and ceriferous. Bdellium has a feeble, peculiar odor, and a bitter taste. PELLETIER states that it consists of—

	Centesimally.
Resin,	59.0
Soluble gum,	9.2
Bassorin,	30.6
Volatile oil and lost,	1.2
	100.0

JOHNSTON represents the composition of the resin of bdellium, by the formula $C_{40}H_{31}O_9$, or $C_{60}H_{42}O_{10}$.

EUPHORBIIUM is the produce of different species of *euphorbia*, a plant growing in the interior of Africa. It exudes in the form of a milky juice, so acrid as to excoriate the fingers, and which hardens by the heat of the sun into irregular yellowish tears. It is nearly inodorous, but its dust excites incessant sneezing. Its taste, at first slight, is afterwards acrimonious and burning; when swallowed, it produces vomiting and purging, and acts as an acrid poison; the persons who grind it suffer from headache and giddiness, and often from delirium. It principally consists of resin and a waxy matter, and a considerable quantity of malate of lime is also present. ROSÉ, in his researches, found euphorbium to contain two distinct resins: one, easily soluble in cold, the other, only soluble in hot alcohol, and, under certain circumstances, susceptible of crystallization. JOHNSTON has also examined these resins, but there is some doubt as to the results of the analysis. ROSÉ assigns the formula $C_{40}H_{33}O_4$ to the crystallizable resin. Euphorbium has also been examined by BUCHNER and HIERBERGER, who regard one of the resins as basic, the other acid.

GALBANUM.—Much uncertainty exists with regard to the plant whence this gum-resin is derived. The Dublin College of Physicians have described galbanum,

on the authority of LINDLEY, as the exudation of the *Opöidia Galbanifera*. DON found an umbelliferous fruit in the galbanum of commerce, which he believed to be that of the plant yielding the gum-resin; and, as it constituted a new genus, he called it *Galbanum Officinale*. But though it is not at all improbable, says Dr. PEREIRA, that these fruits are the produce of the galbanum plant, yet no proof of this has been hitherto adduced, and Dr. LINDLEY, therefore, very properly asks, *Did the fruit found upon the gum really belong to it?*

It has not yet been precisely ascertained where galbanum is produced. DIOSCORIDES says it is obtained in Syria; a statement which is, perhaps, correct, though hitherto no evidence of this has been acquired. It is not improbable that it is also procured in Persia, or even in Arabia, as suggested by Dr. ROYLE. *Opöidia Galbanifera* grows in the province of Khorasan, near Durrood. The German pharmacologists distinguish two varieties—*Galbanum Levanticum* and *Galbanum Persicum*. The names indicate the localities whence they are supposed to be derived.—*Pereira*.

DESCRIPTION.—Galbanum generally occurs in brownish, or dark brownish-yellow, irregular masses of large size, apparently composed of agglutinated tears. Some of these, when broken, appear translucent, and of a bluish, or pearl-white color. Fragments of the stem and other similar impurities often pervade the tears; and, to remove these, the galbanum is generally subjected to fusion and strained.

Another variety of galbanum is known, but it is comparatively rare. It is in distinct, globular, yellowish tears of about the size of a pea, possessing a feebly resinous and yellow fracture.

PROPERTIES AND COMPOSITION.—Galbanum has a hot, acrid, and bitter taste, and a peculiar, balsamic odor. When subjected to cold, it is rendered brittle, and may be easily pulverized.

It has been analyzed by several chemists. PELLETIER's results are as under:—

	Centesimally.
Resin,	60.86
Gum,	19.29
Volatile oil and loss,	6.34
Ligneous matters and impurities,	7.52
Bimalate of lime,	traces.
	100.00

MEISSNER's results, appended, seem much more accurate:—

	Centesimally.
Resin,	65.8
Gum,	22.6
Bassorin,	1.8
Volatile oil,	3.4
Bitter matter, with malic acid,	0.2
Vegetal remains,	2.8
Water,	2.0
Loss,	1.4
	100.0

The volatile oil of galbanum is obtained by submitting the gum-resin, with water, to distillation. It is colorless and limpid. Its odor is like that of galbanum and camphor; its taste is hot, afterwards cooling and bitterish. It is soluble in alcohol, ether, and fixed oils.

The resin of galbanum is dark yellowish-brown, transparent, brittle, and tasteless; soluble in alcohol and ether; scarcely so in spirit containing fifty per cent. of water, or in almond oil; very slightly soluble in oil of turpentine, even when aided by heat. It dissolves in sulphuric acid, forming a dark yellowish-brown liquid.

PELLETIER states that galbanum resin has the remarkable property of yielding an indigo-blue oil when heated to from 248° to 266°. JOHNSTON assigns the formula $C_{40}H_{27}O_7$, as representing the composition of the resin.

USES.—Galbanum is principally employed in medicine; it is administered internally in catarrhs, sometimes in amethorrhoea and chronic rheumatism. Externally, it is applied as a mild stimulant, resolvent, or suppurant, in indolent swellings.

GAMBOGE—*Gomme gutte*, French; *Gutti*, German; *Cambogia*, Latin—is, according to GRAHAM, the produce of *Hebradendron Cambogioides*, a native of Ceylon. Gamboge appears to have been first noticed in 1605 by CLUSIUS, who received some of it in 1603 from PETER GARET of Amsterdam. Admiral VAN NECK had brought this from China, and, according to him, its oriental name was *Ghittaimou*. In Siam it is obtained, says KONIG, by fracturing the branchlets and leaves, when a yellow milky juice exudes, which is collected either upon the leaves of the tree, or in cocoa-nut shells, from which it is transferred to flat earthen vessels, and allowed to inspissate in the atmosphere; it is finally enveloped with leaves. The cylindrical kind of gamboge is resolved into this form by being deposited, while semi-fluid, in joints of the bamboo.

MURRAY states that gamboge is obtained in Ceylon by wounding the bark of the tree, at the time of flowering, with a sharp stone.

DESCRIPTION.—For the delineation of the different varieties of gamboge, the Editor has to resort to the *Materia Medica* of Dr. PEREIRA as the best source of information on the subject. That eminent authority says:—Two kinds of gamboge are described by pharmacological writers—the Siam and the Ceylon. Of these the first only is known in commerce.

1. *Siam Gamboge*.—This is the gamboge of the shops. It is brought to this country sometimes direct from Siam; at other times indirectly by way of Singapore, Penang, or Canton. It presents itself in commerce in three forms:—1, in rolls, or *solid* cylinders; 2, in pipes, or *hollow* cylinders; 3, in cakes or amorphous masses. The first two varieties are known commercially as *pipe* gamboge. The commonest pieces of the above are called *coarse* gamboge.

a. *Pipe gamboge* consists of cylindrical pieces, varying in size from one to three inches in diameter. Some of them appear to have been formed by rolling; but many of them are striated, from the impression of the bamboo into which the gamboge juice has been run, and, not unfrequently, portions of the stem are still adherent. The gamboge cylinders are sometimes distinct, and covered externally with a dirty greenish-yellow dust; at other times agglutinated, or even folded so as to form masses of varying sizes and shapes.

Pipe gamboge occurs in all qualities, the finest and the worst specimens having this form. *Fine gamboge* is brittle and devoid of odor. It has very little taste at first; but, after some time, it causes an acrid sensation in the throat. Its fracture is conchoidal, and the resulting surfaces are opaque reddish-yellow, with a glimmering lustre. It is completely dissolved by the successive action of ether and water. With a sufficient quantity of the latter fluid, it forms a yellow emulsion, the films of which are good microscopic objects for the observation of *active molecules*. The powder of fine gamboge is bright yellow.

Inferior qualities of this gum-resin are harder, more earthy in fracture. The fresh surfaces are brownish or greyish-yellow, frequently with black spots from the intermixture of foreign bodies. Ether and water successively employed do not completely dissolve it. Iodine readily detects starch in the cooled decoction by the green color which it gives rise to.

b. Lump or cake gamboge occurs in masses of several pounds' weight. Its quality is inferior to the finest pipe kind. Internally, fragments of wood, twigs, and air-cells may be observed. In most of its characters it agrees with the inferior qualities of pipe gamboge, and, like these, contains starch.

2. *Ceylon or Cingalese Gamboge*.—Dr. PEREIRA was unacquainted with this kind of gamboge, which is unknown in English commerce. According to Dr. CHRISTISON, it is usually in small, irregular fragments; but, as originally collected, is in flattish round masses—as if moulded in shallow bowls—weighing about a pound or upwards, and it appears to be composed of aggregated irregular tears, with interspaces and cavities, which are lined with a dark pulverulent matter, or with a powder of an earthy appearance. Altogether it seems a very coarse article. It forms, with great ease, an emulsion nowise inferior in smoothness, and very little, if at all, in brightness of tint, to that of the very best pipe gamboge of Siam.

PROPERTIES AND COMPOSITION.—The properties of gamboge have been, to some extent, treated of in the foregoing description. The following are additional reactions:—

Gamboge affords orange-red tinctures with ether and alcohol, which, when dropped on water, yield, on the evaporation of the solvent, thin, bright yellow, opaque films, which readily dissolve in caustic potassa. The resinous portion of gamboge, of which these films are constituted, has been termed by JOHNSTON gambogic acid. The potassa salt, obtained as just noted by the solvent power of the alkali, gives with acids a yellow precipitate of gambogic acid; with acetate of lead, yellow; with sulphate of copper, brown; and with the salts of iron, dark brown deposits.

Should it be necessary, as it sometimes has been in medico-legal cases, to detect the presence of gamboge amongst other vegetal products, as in pills, *et cetera*, the following simple, but sure, course of procedure may be adopted:—

Digest one portion of the suspected substance in alcohol, and another in ether, and subject the tinctures to the above-mentioned tests. Though the yellow resin of New Holland, the produce of the *Xanthorrhoea*

Hastilis, has a similar appearance, yet its chemical reactions with the tests above-mentioned are very different. Should the yellow coloring matter of turmeric, saffron, or rhubarb be taken, at first sight, for that of gamboge, the examination with acids, acetate of lead, sulphate of copper, and salts of iron successively, may be accepted as positive.

Dr. CHRISTISON gives the following as the centesimal composition of gamboge:—

Siam Gamboge.			
	Pipe.	Cake or Lump.	Cones.
Resin,.....	72.5	64.7	48.2
Soluble gum, ..	22.7	20.3	15.2
Woody fibre, ..	trace	5.3	13.3
Fecula,.....	—	5.6	14.5
Moisture,.....	4.8	4.1	8.8
	100.0	100.0	100.0

Ceylon Gamboge	
Resin,	71.2
Soluble gum, ..	19.9
Woody fibre, ..	5.7
Water,	3.2
	100.0

GAMBOGIC ACID.—Syn. Gambogic acid—Resin.—It has a deep orange color, and communicates a yellow tint to ten thousand times its weight of alcohol. It is soluble in this menstruum, and still more so in ether. Water does not take up any of it. When subjected to a heat of about 400° it is partially decomposed, so that while one portion is soluble in alcohol, as the original resin, the other is insoluble. Gamboge resin forms numerous salts. Its composition has been represented by the above chemist as $C_{40}H_{22}O_6$. The gum of gamboge seems to be identical with arabin, and like it readily dissolves in water.

The fecula found in the inferior kinds of gamboge is probably an adulterant.

To a small extent gamboge is employed as a water-color; but its principal application is in medicine. It is seldom administered *per se*, owing to its tendency to create nausea and vomiting; but, when combined with milder purgatives, it has been found to be a valuable remedy in constipation; in cerebral affections, as apoplexy; in dropsy; and as an anthelmintic. The full dose of it is said to be from ten to fifteen grains. In excessive quantity it acts as an acid poison. Dr. PEREIRA records that a drachm administered to a human subject, caused horrible vomiting and purging, followed by syncope and death. No effective antidote is known. HAHNEMANN has, indeed, recommended carbonate of potassa as a means of diminishing the violence of the topical action of gamboge.

MYRRH.—*Myrrhe*, French; *Myrrha*, German; *Myrrha*, Latin. This well-known gum-resin is the spontaneous exudation of the *Balsamodendron Myrrha*. It is repeatedly mentioned in the Old Testament, the earliest allusion being in Genesis, from which it appears that 1729 B.C. it was an article of Eastern commerce. It seems to have been made use of by DEMOCRATES. DIOSCORIDES enumerates several varieties of it; one named the *Troglodytica* being the best. According to some ancient writers, this gum-resin received its

appellation from MYRRHA, the daughter of CIMFRAS, king of Cyprus, who, after committing criminal acts, absconded to Arabia, and was transformed into a tree, which ever afterwards bore her name.

The myrrh tree was not fully known until EHRENBURG, in 1825, returned from his travels with HEMPRICH in Asia and Africa, bringing with him a specimen, which has been delineated and depicted by NEES VON ESENBECK.

DESCRIPTION.—Myrrh, says Dr. PEREIRA, is imported from the East Indies in chests containing from one to two hundredweight each. Formerly the finest kind was brought from Turkey, and an inferior one from the East Indies; but, at the present time, nearly the whole comes from India. Sometimes the same chest contains myrrh of all qualities, which is then termed *myrrh in sorts*; but commonly it is imported more or less assorted.

Myrrh of first quality.—Turkey myrrh occurs in pieces of irregular forms and of variable sizes, consisting of tears—either distinct or agglomerated—usually covered with a fine powder or dust. The color varies, being pale reddish-yellow, red, or reddish-brown. The pieces are fragile, semi-transparent, with a dull, and in part splintery, fatty kind of fracture. In consequence of imperfect desiccation, the largest and finest pieces often present internally, opaque, whitish, or yellow striae, or veins, which have been compared by DIOSCORIDES, PLINY, and many others, to the white marks on the nails. The purest, palest, and most odorous pieces are sold as *picked myrrh*.

Myrrh of second quality consists of distinct tears or grains, which are rounded or irregular, and vary in size from that of a pin's head to a peppercorn, none of them in Dr. PEREIRA'S specimens being so large as a small pea. They are somewhat shiny, more or less transparent, and vary in color from pale or whitish-yellow to reddish-brown. It consists of tears of myrrh, intermixed with fragments of gum-arabic, and of some resin very like mastic or juniper. Many druggists regard it as merely the siftings of the finest kind, but Dr. PEREIRA does not agree with this opinion.

Myrrh of third quality.—Formerly this was the only kind imported from the East Indies. It occurs in pieces, which are darker-colored than those of the so-called Turkey myrrh, and the average size of which does not exceed that of a walnut. It is often mixed with other matters, particularly with *Indian bdellium*, and with a substance of similar appearance to dark-red colored Senegal gum.—*Pereira*.

PROPERTIES AND COMPOSITION.—The odor of myrrh is peculiar, but balsamic and fragrant; the taste is bitter, aromatic, and somewhat pungent. Water dissolves the gum principally, while alcohol and ether take up the volatile oil and resin. Myrrh is readily dissolved by the alkalis. When it is subjected to the action of nitric acid, a vinous hue is produced. According to PELLETIER it consists of thirty-four per cent. of resin and sixty-six of gum. RUICKHOLDT states that it contains, when of the best quality, between forty-four and forty-five per cent. of resin. BRANDES and BRACONNOT have also analysed it, with the following results:—

	Centesimally represented	
	Brandes	Bracconot
Volatile oil,.....	2.60	2.5
Resin,.....	27.80	23.0
Gum { Soluble,.....	54.98	46.0
{ Insoluble,.....	9.32	12.0
Salts—benzoates, malates, phosphates, sulphates, and acetates of potassa and lime,.....	1.36	—
Impurities,.....	1.60	16.5
Loss,.....	2.94	—
	100.00	100.0

According to **BRANDES**, the 27.80 per cent. of resin found by his analysis, consisted of 22.24 soft, and 5.56 of hard resin, the two soluble in alcohol. The former he distinguishes as odorous, and insoluble in ether. **UNVERDORFEN** regards it as a compound of hard resin and volatile oil. The hard resin is characterised as inodorous, soluble in the caustic alkalies, but not taken up by ether. The resin prepared by **RUICKHOLDT** was of a brown color, fused at a temperature below 212°, and slightly retained the taste and odor of the gum-resin. By subjecting it to heat, he obtained a modified resin, which he has termed myrrhic acid.

The volatile oil of myrrh has the odor and taste of myrrh; it is soluble in alcohol, ether, and the fixed oils; it is thin, but has a specific gravity higher than that of water. It is devoid of color, but becomes yellowish by keeping, probably from the absorption of oxygen. It forms red menstrua, with sulphuric, nitric, and hydrochloric acids. When exposed to the atmosphere, partial evaporation occurs, and a glutinous, varnish-like magma remains.

The Editor learns that myrrh is often mixed with Indian bdellium—the produce of the *Amyris commiphora*. *Bdellium*, in appearance and taste, is often very similar to myrrh, but differs in odor, and is characterized by its great amount of bassorin. Besides this, it is often mixed with another substance, for the detection of which **BLEY** and **DIESEL** give directions as follows:—

Pseudo-myrrh, which has been frequently found incorporated with the genuine myrrh, consists of large pieces of different forms, the majority of them seeming to be fragments of a cylindrical body; they are coated externally with dust, and have a dirty reddish-brown color; the surface of fracture is tolerably even, of vitreous lustre, brownish-yellow color, and nearly as transparent as Senegal gum. It has a faint myrrh-like odor, and a disagreeable, bitter, somewhat balsamic taste. Nitric acid dissolves it, yielding a bright yellowish liquid, from which water separates small yellowish particles. Genuine myrrh yields with nitric acid a transparent dirty-yellow liquid. *Bdellium indicum* is not dissolved by nitric acid; it softens, becomes whitish and opaque. Bibulous paper, moistened with the alcoholic extract of myrrh, and then with nitric acid, acquires the blood-red color first observed by **BONASTRE**; *bdellium* and pseudo-myrrh exhibit only a yellow or brownish coloring. *Bdellium indicum* is, moreover, distinguished by its greenish-brown hue, its more terebinthinate odor, and bitter and somewhat acid taste. It becomes viscous when held for some time between the fingers. Myrrh yields a bright

golden-yellow tincture, and an opaque whitish residue; pseudo-myrrh, a high yellow one, and a semi-transparent residue; *myrrha indica*, a dark-yellow tincture, and an opaque residue. An addition of water produces in the first and last a milky turbidness, and in the second no change. Nitric acid—six drops to twenty of the tincture—yields with *myrrha electa* a yellowish-white opacity, upon which, after a time, the periphery of the liquid acquires a bright violet color, while the centre remains yellow. *Myrrha indica* behaves similarly, only that the tint is darker; pseudo-myrrh does not exhibit this reaction. Fuming nitric acid produces with the tincture of *myrrha electa* an amber-brown, and finally a dark violet color; on evaporation, a dark gamboge-looking residue is left; *myrrha indica* exhibits the same reaction; pseudo-myrrh experiences no change. *Bdellium indicum* and *africanum* are distinguished by their not assuming a violet hue on their treatment with nitric acid. About two grains of myrrh, shaken with an ounce of water and filtered, yield with solutions of salts of the oxide of lead a considerable precipitate. *Bdellium indicum*, treated in the same manner, exhibits scarcely any opacity.

USES.—Like most of the other gum-resins, myrrh is employed only in medicine; it is useful in disordered conditions of the digestive organs; in excessive secretions from the mucous membrane; and, externally, as a dentifrice, and as a gargle for ulceration of the throat in the form of tincture.

OLIBANUM.—*Oliban*, French; *Oelbaumharz*, German; *Olibanum*, Latin. This gum-resin, employed by the ancients in their religious rites under the name of *frankincense*, and first mentioned by **MOSES**, is derived from the *Boswellia Thurifera*, a terebinthaceous tree, inhabiting the mountainous parts of Coromandel.

DESCRIPTION.—**Dr. PEREIRA** describes it as consisting of round, oblong or ovate, pale-yellowish, semi-opaque, fragile tears, having a balsamic resinous odor. **JOHNSTON** is of opinion that it is a mixture of two distinct gum-resins. The one he delineates as consisting of opaque, dull, hard, brittle pieces, which, when introduced into alcohol, become almost immediately white and opaque, from a white powdery coating or crust left on their surface as the soluble portion is taken up. This variety constitutes the larger portion of the olibanum of commerce, and is the more fragrant when burned. It contains an acid resin and volatile oil.

The second variety is characterised as being in clearer, more yellow, less brittle, opaque pieces, generally in long tears as they have flowed from the tree, containing less gum than the other kind, and becoming clear and transparent when immersed in alcohol. All the tears of olibanum experimented upon by **Dr. PEREIRA** became opaque when introduced into alcohol.

COMPOSITION.—Olibanum has been examined by **BRACCONOT**, who gives the following as its centesimal composition:—

	Per cent.
Resin,.....	56.0
Gum,.....	30.0
Volatile oil,.....	8.0
Matter like gum, insoluble in water and alcohol,.....	5.2
Loss,.....	0.8
	100.0

Dr. STENHOUSE, who examined the volatile oil of *olibanum*, found it to be colorless, and similar to turpentine, but possessed of a more agreeable odor. Its composition is represented by the formula $C_{25}H_{25}O$.

JOHNSTON has distinguished two distinct resins, produced by both varieties of the gum-resin before-mentioned. The resin from the first of these gave the composition $C_{40}H_{32}O_6$. That from the second, consisting of the clearer, yellower, elongated tears, resembles colophony, and its formula is $C_{40}H_{32}O_4$.

USES.—*Olibanum* is, to a great extent, disused for medical purposes. It was formerly administered in chronic diarrhoea, old catarrhs, and in affections of the chest. It is sometimes employed for fumigation, and enters into the incense employed in the services of the Roman church.

OPOPONAX.—*Opopanax*, French, German, and Latin.—This gum-resin is the inspissated juice of the *Opopanax Chironium*, a plant flourishing in Greece, Italy, Sicily, and in the South of France, and bearing a great similarity to parsnip. It was employed by HIPPOCRATES, and is mentioned both by DIOSCORIDES and by THEOPHRASTUS.

Opopanax occurs in reddish tears and lumps, tasting acrid and bitter, and possessing a mouldy, disagreeable odor. The following is its constituents, as ascertained by PELLETIER :—

	Centesimally.
Resin,	42.0
Gum,	33.4
Lignin,	9.8
Starch,	4.2
Wax,	0.3
Extractive,	1.6
Malic acid,	2.8
Volatile oil, traces of caoutchouc, and loss,	5.9
	100.0

On evaporating the spiritous solution of opopanax, a transparent brown resin, having a peculiar odor, is obtained. It readily fuses at 212° , and, after remaining for a short time at that temperature, becomes brittle upon cooling. It dissolves in alcohol and ether, and in the caustic alkalis. The alkaline solution is reddish, and parts with the resin, on the addition of hydrochloric acid, in yellow flocculi. Its composition, as it exists in the natural gum-resin, is as under :—

	At weight	Centesimally	
		Theory.	Johnston.
40 Eqs. Carbon,	240	63.67	64.01
25 Eqs. Hydrogen,	25	6.63	6.75
14 Eqs. Oxygen,	112	29.70	29.24
1 Eq. Opopanax resin, ..	377	100.00	100.00

USES.—Opopanax was formerly employed in medicine, but it is now banished from the *Materia Medica* as enumerated in the British Pharmacopoeias. It is adapted to the same cases as the other gum-resins of this class. Dr. PEREIRA is of opinion, that it is more allied to ammoniacum than to any other of these substances.

SAGAPENUM.—*Sagapenum*, French and German; *Sagapenum*, Latin.—Sagapenum is mentioned, says Dr. PEREIRA, by HIPPOCRATES, DIOSCORIDES, and PLINY. The latter calls it *sacopenium*. DIOSCO-

RIDES says it is a liquor obtained from a ferulaceous plant growing in Media. Nothing is known with respect to the plant yielding sagapenum. WILDENOW considered it to be *Ferula Persica*, and it has been followed by SMÄNGEL, and others; but there is no evidence to prove that sagapenum is obtained from a *Ferula*, for the statement of DIOSCORIDES cannot be admitted as having much weight.

BRANDES' analysis of sagapenum gave the following results :—

	Centesimally.
Resin,	50.0
Gum, with calcareous salts,	32.5
Volatile oil,	2.5
Bassorin,	4.2
Malate and phosphate of lime,	1.1
Impurities,	4.2
Water,	4.5
	100.0

Sagapenum of the finest kind consists of masses made up of agglutinated, brownish-yellow, semi-transparent tears, resembling galbanum, but having a darker color and a more alliaceous odor. A more common sort occurs in soft, tough masses, in which no distinct tears are to be seen. Its taste is hot and acrid, and, when heated, it evolves a much more aromatic and agreeable odor than galbanum. It is imported from the Levant.

The oil of sagapenum has a mild bitter, alliaceous taste, subsequently becoming hot; its odor is also garlicky. It is of a pale yellow color, dissolves in alcohol and ether, and is reddened by sulphuric acid. Its specific gravity is greater than that of water.

The resin of sagapenum has been examined by JOHNSTON, who gives, as the representative of its composition, the formula $C_{40}H_{32}O_6$. It possesses a strong garlic odor, and easily fuses, becoming fluid at 212° . Ether resolves it into two resins :—

1. The resin *insoluble in ether* is devoid of taste and odor, and is of a brownish-yellow tint. It is soluble in alcohol and the alkalis, but is not taken up by oils of turpentine and almonds.

2. The resin *soluble in ether* possesses the odor of sagapenum in a slight degree; its taste is mild, subsequently bitter; its color, reddish-yellow. It is soluble in alcohol, and partially so in oils of turpentine and almonds. Sulphuric acid dissolves it, forming a blood-red menstruum, from which a violet-tinged matter is separated by the addition of water.

USES.—The medicinal effects and uses of sagapenum are similar to those of asafetida,—see page 322. It is now very little employed.

The Editor thinks it most remarkable that so little is really known with respect to the previously-cited compounds. There is now a great field open to young chemists to investigate their nature and true composition, *et cetera*, so as to remove many of the inaccuracies regarding them.

STATISTICS.—The Returns of the Board of Trade for 1850 to 1855 only enumerate Ammoniacum, Asafetida, Euphorbium, Gamboge, Myrrh, and Olibanum. Annexed are the imports and exports of these for the years 1850, 1851, 1852, 1853, 1854, and 1855 :—

Years ending 5th January, 1850.		IMPORTS.					
	Cwt.	1851. Cwt.	1852. Cwt.	1853. Cwt.	1854. Cwt.	1855. Cwt.	
Ammoniacum,	832	891	304	60	19	—	
Asafetida,	820	1,922	1,167	2,170	1,555	1,251	
Euphorbium,	17	12	14	—	—	99	
Gamboge,	561	1,490	701	455	173	259	
Myrrh,	545	620	814	282	579	689	
Olibanum,	4,539	11,450	8,837	9,029	13,393	10,817	

Years ending 5th January, 1850.		EXPORTS.					
	Cwt.	1851. Cwt.	1852. Cwt.	1853. Cwt.	1854. Cwt.	1855. Cwt.	
Ammoniacum,	705	222	319	246	168	79	
Asafetida,	507	1,049	1,176	904	731	795	
Euphorbium,	—	—	—	—	—	4	
Gamboge,	426	153	335	1,056	235	373	
Myrrh,	113	263	535	341	272	180	
Olibanum,	4,798	11,990	8,739	8,892	12,756	11,757	

GUN-COTTON.—*Colton-poudre*, French.—Some years ago this substance created quite a *furor* in the scientific world; but the expense of gun-cotton is considerably higher than that of gunpowder, and this with other drawbacks has been a great obstacle to its being extensively used. Ordinary cotton is one of the almost innumerable forms of lignin, a compound of carbon, oxygen, and hydrogen; but, by subjecting cotton to the action of nitric acid, a new element enters into the composition—namely, nitrogen, which is found in nearly all explosive bodies.

The action of nitric acid on vegetal matter had long attracted the attention of chemists before the discovery of the remarkable detonating compound now under notice. In 1813, BRACONNET gave an account of a new substance obtained by the action of concentrated nitric acid on starch, sawdust, linen, and cotton wool. He named this xyloidin, from the Greek word signifying wood, and described it as being white, pulverulent, neutral, and very inflammable. It is easily formed by boiling starch for a few moments in concentrated nitric acid, until solution takes place; on pouring the resultant into cold water, the xyloidin is precipitated, and may be collected and exsiccated. In 1838, PELOUZE called the attention of the Academy of Sciences to the properties of xyloidin, which he observes is very combustible, taking fire at 365°, burning with great rapidity, and almost without residue. This property led him to an experiment which he thought susceptible of some applications, especially in artillery. By plunging paper in nitric acid, specific gravity 1·5, leaving it there the requisite time for the acid to permeate the paper, which is usually accomplished in two or three minutes, then withdrawing it, and, lastly, washing it in water, a kind of parchment impermeable to moisture, and extremely combustible, is obtained. DUMAS proposed to name the compound *nitramidine*, and mentions the application of paper and pasteboard prepared by nitric acid for fireworks.

At a meeting of the British Association at Southampton, in 1846, it was stated that Professor SCHÖNBEIN had discovered a mode of rendering cotton so detonating as to form an excellent substitute for gunpowder. Soon after this announcement, Professor OTTO of Brunswick published an account of an explosive cotton, as did also MOREL of Paris, and BÜTTGER of Frankfort. SCHÖNBEIN undoubtedly, as

DUMAS admits, deserves the honor of having been the first to show that the products of the action of nitric acid upon lignin are superior in explosive energy to gunpowder; but it must be recorded that, as far back as 1832, ROBIQUET produced an insoluble powder, explosive when heated, by the addition of water to a solution of sawdust in strong nitric acid. In April, 1847, SCHÖNBEIN's patent was enrolled; the specification states, that in preparing the cotton the patentee uses nitric acid of specific gravity 1·45 to 1·50, and sulphuric acid of specific gravity 1·85. These acids are to be mixed in the proportion of three parts of the latter to one of the former; the mixture is allowed to cool down to between 50° and 60°, and then rough cotton, free from all extraneous matter, is immersed in the liquid, in as open a state as possible, in a porcelain vessel. When thoroughly soaked, the excess of acid is to be drawn or poured off, and the cotton squeezed lightly with an earthen presser to separate the principal part of the acid. The cotton is covered over and left for an hour, then pressed, and well washed in running water, to get rid of all free acid; it is next to be partially exsiccated by pressure, and to insure its freedom from acid, it is to be washed in a dilute solution of carbonate of potassa, made by dissolving one ounce of this salt in a gallon of water; it is then put in a press, and the excess of alkaline solution squeezed out, leaving the cotton nearly dry. It is next washed in a solution consisting of one ounce of pure nitrate of potassa in one gallon of water, and when again pressed is dried in a room heated by steam or hot water to the temperature of from 150° to 170°. The saltpetre appears to increase the explosive force of the cotton, but it is not absolutely necessary. Of the cotton thus prepared, three parts are said to be equal in force to eight parts of Tower-proof gunpowder.

A simpler method of preparing gun-cotton in small quantities was proposed by Mr. THOMAS TAYLOR in 1846, which is to mix in any convenient glass vessel an ounce and a half, by measure, of nitric acid—specific gravity 1·45 to 1·50—with an equal quantity of sulphuric acid—specific gravity 1·80. When the mixture has cooled, place one hundred grains of fine cotton wool in a mortar, pour the acid over it, and with a glass rod imbue the cotton as quickly as possible with the acid. As soon as the cotton is completely satu-

rated, remove the acid, and, with the aid of a pestle, quickly squeeze out as much liquid as possible. Throw the mass into a basinful of water, and thoroughly wash it, either in successive portions of water or under a tap, until the cotton has not the slightest acid taste. Finally, squeeze it in a linen cloth, and dry it in a water-bath. Nitric acid of the specific gravity of 1.50 answers better than that of 1.45, the cotton being much less acted upon by the strong acid. Nitric acid of the specific gravity 1.36 converts the cotton into a gelatinous mass.

Gun-cotton is considerably heavier than unprepared cotton, and may be distinguished therefrom by its harshness, and by the crepitating sound produced when pressed by the hand. When well made, there is scarcely any change in color or general appearance. It may also be known from common cotton by its electric condition; for if a portion be pulled briskly between the finger and thumb of a dry hand, the fibres will adhere with great tenacity. If a strip of prepared paper be thus treated, it will, on presenting one end to the knuckle, be alternately attracted and repelled, and thus part with its electricity. Gun-cotton is also perfectly soluble in ether, and if the solution be poured on the surface of cold water, the xylodiu yields an opaque film thereon, which, when collected and dried, forms a remarkably explosive paper.

The detonating character of gun-cotton appears to be due to the formation of xylodiu in the tubes and upon the exterior of the cotton fibre, under the action of the nitric acid. Gun-cotton explodes with very great rapidity at from 350° to 400°. If a little gunpowder be placed on a sheet of writing paper, and a small piece of gun-cotton be laid lightly upon it, and the whole held about a foot above the flame of a lamp or candle, the heat will soon be sufficient to ignite the cotton, but the powder will not be kindled; and, although the cotton explodes in contact with the powder, its action is so rapid that there is not time enough to raise the gunpowder to the temperature required for its explosion. This great rapidity of action is opposed to its utility for propulsive purposes. It is well known to practical men that a tardily-exploding material is the best for artillery practice. Thus, when a slow powder is used, the ball acquires a slight degree of motion, which is imparted to the air in front of it, before the full power of the detonation is exerted; and that motion is gradually increased during the remainder of the explosion. But if the action takes place too quickly, the full force of the propelling power comes into play before the ball is in motion, and the bursting of the gun is the probable consequence. This is the reason why the fulminates of mercury and silver have not been more extensively used in warfare.

When gun-cotton has been carefully prepared, the products of its combustion are carbonic acid, aqueous vapor, and free nitrogen. In some cases nitrous acid is produced, owing to defective washing; and when nitrate of potassa has been employed, or, in fact, a solution of any salts, a dense white vapor accompanies the explosion. The quantity of water produced during the decomposition of the cotton by heat is so great, as to constitute an objection to its use

in fire-arms. Its hygrometric condition also impedes its utility; for if a quantity be exposed for an hour or two to a damp atmosphere, it absorbs nearly its own weight of water, and requires re-drying before it can be employed; it cannot be protected from atmospheric moisture by compression into cartridges, as in that state it does not explode with certainty. The idea of using the fulminating cotton as a substitute for gunpowder for artillery purposes, seems to be completely abandoned; but on account of the small quantity of smoke given off, as well as on account of its enormous force, it is much used for mining purposes, the proportionate quantity employed being a fourth of that of powder.—Tomlinson.

In the explosion of gun-cotton there appear to be found very decided quantities of nitrous and of hydrocyanic acid. The former corrodes fire-arms, and the latter vitiates the surrounding air in a mine.

The most recent and best information on gun-cotton and its substitution-compounds is given in a paper by Mr. EDWARD HADOW, from which the following interesting details are transcribed.

Analyses of gun-cotton have been published by PELOUZE, PELIGOT, GLADSTONE, PORRETT, RANSOME, and likewise by SCHÖNBEIN; they exhibit, however, a remarkable want of agreement with each other, both in the formulae to which they give rise, and in the per-centage increase of weight which they would represent the cotton to have obtained on its transformation into gun-cotton.

PELOUZE states that cotton constantly gains from seventy-four to seventy-six per cent., giving the formula $C_{24} H_{17} O_{17}, 5 NO_6$, corresponding to an increase of seventy-five per cent. exactly. PELIGOT's formula is $C_{12} H_8 O_6, 3 NO_6$, according to which the gain must be 94.4 per cent. RANSOME obtained $C_{12} H_8 O_{10}, 2 NO_6$, which represents an increase of 65.4. Dr. GREGORY states it to be 69.5, which corresponds with that required by the formula which GLADSTONE ascribes to the most explosive gun-cotton, $C_{24} \left\{ \begin{matrix} H_{15} \\ 5 NO_6 \end{matrix} \right\} O_{20}$,

while the formula of PORRETT and TESCHEMACHER, $C_{12} H_8 O_6, 4 NO_6$, would double the original weight of the cotton. SCHÖNBEIN merely gives the per-centage of carbon, nitrogen, hydrogen, and oxygen, from which the lowest formula that can be calculated corresponds nearly to $C_{47} H_{31} O_{68} N_{10}$. In consequence of this disagreement between the formulae, giving rise to so marked a difference in the per-centage increase of weight deduced from them, it was evident that a careful determination of the weight actually acquired by cotton, after immersion in acids, could alone throw much light on the matter, by pointing out the formula upon which most reliance was to be placed, and from which the composition of the soluble variety might be determined, provided that it were indicated by a definite and constant increase of weight. While ascertaining this point, HADOW was anxious likewise to discover what strength and what proportions of acids were capable of producing the soluble gun-cotton, as well as whether there were more than one such compound; expecting that, if such were the case, there would be always an augmentation of weight closely correspond-

ing to two or more numbers from which formulæ might be calculated, or by which at least the results of analyses might be controlled.

In the preparation of these compounds, nitric acid was not used alone, since a very slight difference in strength produced a great difference in the result. HO, NO_3 gives an insoluble product, while $\text{HO, NO}_3 + \text{HO}$ destroys the texture of the cotton; and having ascertained that when sulphuric acid is used, no trace of it exists in any of the compounds, a mixture of the two was always used; the latter acid being advantageous for the purpose of increasing the bulk of the mixture, retaining the water abstracted from the cotton, and preventing the solution of the compound, which takes place to a greater or less extent in nitric acid *per se*. The mixtures were likewise made in atomic proportions, that their formulæ might be easily retained in the memory, and similar mixtures be prepared from acids of various strengths. After some trials, those which contained one equivalent of monohydrated nitric acid with two equivalents of monohydrated sulphuric acid, proved to be best; and mixtures being made with the acids in this proportion, and from one to five additional equivalents of water, the fifth was found to disintegrate the cotton. The results obtained from one hundred of cotton were as follow:—

$\left. \begin{array}{l} \text{HO, NO}_3 \\ 2 (\text{HO, SO}_3) \end{array} \right\} 2 \text{HO} = 177$	} Insoluble in ether + one-eighth alcohol except the last, which is slightly attacked.
$\left. \begin{array}{l} \text{HO, NO}_3 \\ 2 (\text{HO, SO}_3) \end{array} \right\} 2 \text{HO} = 176$	
$\left. \begin{array}{l} \text{HO, NO}_3 \\ 2 (\text{HO, SO}_3) \end{array} \right\} 3 \text{HO} = 171.7$	
$\left. \begin{array}{l} \text{HO, NO}_3 \\ 2 (\text{HO, SO}_3) \end{array} \right\} 4 \text{HO} = 157$	} Very soluble.
$\left. \begin{array}{l} \text{HO, NO}_3 \\ 2 (\text{HO, SO}_3) \end{array} \right\} 5 \text{HO} = \text{about } 140$	
	} Soluble in great measure.

The interval between the third and fourth appeared in some degree to correspond to what had been expected. That between the fourth and fifth was doubtful, from the loss of the latter, and from its apparently containing an admixture of unchanged cotton; but on trying fractional additions of water, a corresponding intermediate increase of weight was likewise produced in the cotton: for example,

$\left. \begin{array}{l} \text{HO, NO}_3 \\ 2 (\text{HO, SO}_3) \end{array} \right\} 3\frac{1}{2} \text{HO} = 166.4$ } $\left. \begin{array}{l} \text{HO, NO}_3 \\ 2 (\text{HO, SO}_3) \end{array} \right\} 3\frac{3}{4} \text{HO} = 160.5$
both compounds proving perfectly soluble. It was likewise found on repeating these experiments, that it was difficult to obtain the same increase of weight unless the mixture corresponded accurately in composition. The cotton in these researches was thor-

oughly exsiccated in a current of dry air at 212° , and in consequence of its hygroscopic properties, was weighed in the same tube in which the desiccation took place. At first the gun-cottons were likewise carefully dried at low temperatures, after thorough washing in distilled water; but the results not being found quite accurate, and a gradual loss of weight being observed at temperatures below 212° , the drying was effected by placing them *in vacuo* over sulphuric acid for twenty-four hours, after which they were found not to sustain the slightest diminution in weight. The acids were also used in large proportion to the quantity of cotton, that the water abstracted might have no appreciable effect in diluting the mixture; and as a precaution, the immersion was continued for several hours, although the full effect appears to be produced in a very short space of time. It was, however, found that, notwithstanding these advantageous conditions for the production of definite compounds, very variable increments of weight were acquired by the cotton, ranging from about forty per cent. upwards.

Immersion in acids previously warmed was then tried, but as the cotton was found to lose weight in proportion to its duration, owing to a slow solution even at 120° , nothing could be learnt from the weighing of the compound; in other respects, however, the result of the experiment with hot acids proved curious and interesting, from the fact that

$\left. \begin{array}{l} \text{HO, NO}_3 \\ 2 (\text{HO, SO}_3) \end{array} \right\} 3 \text{HO}$, which at 60° gave rise to an almost insoluble compound, produced at 130° one perfectly soluble in ether + $\frac{1}{2}$ alcohol: the other acid mixtures, containing more than three equivalents of water, produced soluble compounds, both at 60° and 130° , but their solutions differed remarkably in one respect; for all soluble products formed at ordinary temperatures, when dissolved in the proportion of six grains to the ounce, yield thick glutinous solutions, while all those which are the result of acids at the temperature of 130° , give perfectly fluid ones, which produce, on drying, membranes far exceeding the former in strength and toughness, and much better adapted to photographic or surgical purposes. By far the best mixture for producing collodion-wool is that re-

presented by the formula $\left. \begin{array}{l} \text{HO, NO}_3 \\ 2 (\text{HO, SO}_3) \end{array} \right\} + 3.5 \text{HO}$, which is obtained by mixing eighty parts by weight of nitric acid, specific gravity = 1.424, with one hundred parts by weight of sulphuric acid, specific gravity = 1.833; as—

$$\begin{array}{lcl} \text{Sulphuric acid, specific gravity, 1.833,} & = & 2 (\text{HO, SO}_3 + 0.33 \text{HO}) = 103.9 \\ \text{Nitric acid, specific gravity, 1.424,} & = & (\text{HO, NO}_3 + 2.81 \text{HO}) = 88.5 \end{array}$$

$$\text{HO, NO}_3 + 2 (\text{HO, SO}_3) + 3.5 \text{HO} = 192.4$$

These specific gravities are especially referred to, from their being those of the acids most frequently met with in commerce. Good collodion-wool is also produced by stronger acids, if there be *not less* water than that required by the formula $\left\{ \begin{array}{l} \text{HO, NO}_3 \\ 2 (\text{HO, SO}_3) \end{array} \right\} + 3 \text{HO}$, and the temperature is raised to 130° ; however, the stronger the acids, the more liable is the collodion-wool to be-

come partially insoluble after drying. If there be less than three additional equivalents of water, the products are equally insoluble whether the acids are employed hot or cold.

Finding that the weighing of the product resulting from the action of warm acids could be of no service in proving the existence of definite compounds, Mr. HARDWICK's suggestion was tried—the effect of reim-

mersing the cotton in a portion of the same cold acid mixture with which it had been previously treated, noting at the same time whether any second increase of weight was obtained. The results were highly satisfactory. For the preparation of the highest compound, a mixture was made of two volumes of the strongest sulphuric and one volume of colorless nitric acid, specific gravity = 1.521.

27.5 grains of cotton, after some hours' immersion, weighed after washing and drying *in vacuo*, 49.88 grains, corresponding to a gain of 81.34 per cent. In this case, it was hardly expected that a second immersion would cause an increase; by experiment it was found to have sustained a slight loss, as it now weighed 49.62, showing that acids have a slight solvent power, even at ordinary temperatures. This increase of 81.34 per cent. in weight does not correspond with any of the analyses hitherto published, although the greatest care was taken to avoid error, on account of the important aid it would afford in deducing a formula for this and other compounds.

Another mixture agreeing with $\left\{ \begin{array}{l} \text{HO, NO}_2 \\ 2(\text{HO, SO}_3) \end{array} \right\} + 4 \text{HO}$, gave at the first immersion an increase of 58.7 per cent.; by a second it was found to have increased to 62.9 per cent., thus fully answering expectations. A third immersion brought it to sixty-four per cent.

On account of the great difference observed between the products of $\left\{ \begin{array}{l} \text{HO, NO}_2 \\ 2 \text{HO, SO}_3 \end{array} \right\} + 3 \text{HIO}$, and the same $+ 4 \text{HO}$, an intermediate mixture was made. The first submersion gave an increase of 67.3 per cent.; a second, 70 per cent.; a third, 71.4 per cent. Hence it was concluded that there were at least three compounds, of which, from one hundred of cotton, there would be obtained quantities approximating to one hundred and sixty-four, one hundred and seventy-two, and one hundred and eighty-two; and it is probable that any acid mixture would produce such a definite compound, were it not diluted at the same time by the water it abstracts, which, when the dilution exceeds a certain point, gives rise to a second compound, the great mass of the liquid probably having but little influence, in consequence of the imperfect diffusion arising from the want of perfect fluidity, and the adhesion to the fibres of the cotton; the washing and *thorough* drying then enable the original acid mixture to raise the second compound to that which would have resulted in the first instance had no dilution occurred. It is evident, also, that the number of immersions required must vary, according as the acid mixture is much within or approaches near to that state of dilution which limits its power of producing a certain compound, a given quantity of water having much more effect in one case than in the other.

In trying the effect of various reagents on gun-cotton, HADWORTH ascertained that it could be perfectly restored to the original cotton, without loss of form, by means of hydrosulphide of potassium, KS, HS. At Dr. MILLER's suggestion, this was made use of, to effect the analysis of the compounds, and to confirm the previous results. An aqueous solution was first tried,

but found to occasion loss of weight, on account of the long boiling required; an alcoholic solution was, therefore, prepared, by *thoroughly saturating* a strong alcoholic solution of sulphide of potassium and hydrogen, by transmitting the gas until it would absorb no more, and ceased to give a precipitate in sulphate of magnesia. As, however, the reduction was found to proceed easily at ordinary temperatures, it proved better to effect the change by continuing the immersion for twenty-four hours, and thus to avoid the risk of decomposition and loss which prolonged seething occasioned. That the cotton so obtained was free from nitrogen-compounds was proved by strongly heating it with caustic potassa, and conducting the gases evolved into a solution of litmus very faintly reddened, when the color remained unchanged; by the close correspondence in the quantity obtained from gun-cotton with that originally used, or the restoration back to the original weight; and by its possessing all the physical characters of common cotton, which differs from all products obtained from it by the action of acids in its depolarising action on light, and in its far greater softness and compressibility when wet, and also by the action of $\text{HO, SO}_3 + \text{HO}$, which dissolves the nitro-compounds, producing a solution which is not blackened below 212° , while common and reduced cotton are completely carbonised below that temperature.

Two combustions of the reduced cotton were made; one, in which the determination of hydrogen failed in consequence of an accident, gave, in one hundred parts, 44.4 of carbon; another, made by Mr. HADWORTH, yielded—

	Found	Calculated
Carbon,.....	44.86	44.44 = 12 C.
Hydrogen,.....	6.64	6.17 = 10 H.
Oxygen,.....	48.50	49.39 = 10 O.
	100.00	100.00

The other products of the equivalents of KS, HS are nitrate of potassa—KO, NO₃—and a little ammonia. No trace of nitrate could be discovered in the solution, which was evaporated to dryness with excess of acetic acid, to expel the nitrous acid. An attempt was made to turn the reaction of KS, HS upon gun-cotton to account in effecting the determination of the nitrogen by this means; but the results were unsatisfactory, in consequence of the co-existence of ammonia and nitrous acid in the liquid. The solution could not be heated to expel the former without risk of loss in the weight of the reduced cotton, neither could the ammonia be retained by addition of an acid, without escape of NO₂, from the action of sulphide of hydrogen and nitrous acid on each other.

A mode altogether different was, therefore, adopted, which consisted in making a solution of the compound in pure sulphuric acid, and, after conversion of the oxides of nitrogen into nitric acid, by means of some oxidating agent, estimating its amount by the method of PELOUZE, depending on its property of converting proto into sesquichloride of iron, and from the amount of the latter calculating the former. Before performing this, the properties of a solution of gun-cotton in sulphuric acid were examined. A portion immersed in cold concentrated sulphuric acid soon dissolves, with-

out evolution of any gas, producing a clear, colorless liquid; if this be poured at once into five or six times its bulk of water, so that the temperature does not rise before dilution takes place, the clear menstruum obtained gives no evidence whatever of nitric acid, or any oxide of nitrogen, even though raised subsequently to the boiling point; neither does it discolor a solution of permanganate or chromate of potassa. If, however, the original liquid in concentrated acid be diluted with only once, or even twice its bulk of water, a violent effervescence ensues, with abundant evolution of nitrous acid— NO_2 —or peroxide of nitrogen— NO_4 —together with carbonic acid. If, again, the solution in strong acid be heated before dilution, carbonic acid is evolved, while the oxides of nitrogen are retained, provided that the sulphuric acid is in different excess; if it now be diluted with water, nitric oxide— NO —escapes with effervescence. It became necessary, therefore, to effect the complete conversion of the nitrogen oxides into nitric acid. After trial of various oxidising agents, the object was successfully attained by the bichromate of potassa, which immediately peroxidises NO_2 and NO_4 , but is without action on NO : hence it was necessary to use a solution of gun-cotton in pure sulphuric acid made in the cold, which was then added to a strong solution of bichromate contained in a retort; the mixture—which immediately acquired a dark-green tint, from reduction of the chromic acid—was carefully distilled, precaution being taken to insure the entire expulsion of the nitric acid, which was then estimated, as above stated, by PELOUZE'S method.

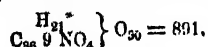
The quantity of cotton in a given sample of gun-cotton having been determined by reduction by KS , HIS , and the nitrogen by the above method, it is easy to see whether the compound contains any equivalents of NO_2 , not displacing a like number of equivalents of HIO . The following results of analysis leave no doubt that it is purely a substitution-compound:—

Compound A.—Produced by action of the strongest acids, and most probably by repeated immersion in any mixture not weaker than $\frac{\text{HO, NO}_2}{2 (\text{HIO, SO}_3)} + 3 \text{HO}$. Quite insoluble in any mixture of ether and alcohol, but soluble in acetic ether. Highly explosive.

- I. 27.5 of pure cotton gave, by three hours' immersion in strongest acid, 49.88 first time; 49.6 second time.
- II. 6.85 of this gun-cotton gave, by reduction, 3.78 of cotton
- III. 6.37 of gun-cotton, by reduction, gave 3.48 of cotton.
- IV. 20.50 of gun-cotton gave $\text{NO}_2 = 10.84$.

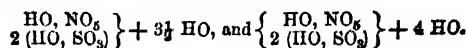
	By analysis.			By calculation $\text{C}_{36} \text{H}_{21} \text{O}_{30} 9 \text{NO}_4$
	I.	II.	III.	
Cotton found...	55.13	51.6	55.19	54.54
$\text{NO}_4 - \text{H}$,	—	—	44.07	45.46
			99.26	100.00

The composition of cotton being fully determined by the analyses of MITSCHERLICH, PELOUZE, and PAYEN, to be in the proportion of $\text{C}_{12} \text{H}_{10} \text{O}_{10}$, the preceding analysis would give rise to the formula,



100 of cotton produced 181.34: by calculation, 183.3.

Compound B.—Produced most probably by any acids of composition intermediate between



That which was examined was obtained by several immersions in $\left\{ \frac{\text{HO, NO}_2}{2 (\text{HIO, SO}_3)} \right\} + 3\frac{1}{2} \text{HO}$. It is explosive, yet perfectly soluble in ether + $\frac{1}{2}$ alcohol; quite insoluble in acetic acid.

- I. 27.6 grains of cotton gave, by first immersion in the above mixture, 46.2 grains; by the second immersion, 47.1; by the third, 47.31.
- II. By reduction, 6.08 grains of the compound gave 3.50 of cotton.

	From synthesis. I.	By analysis. II.	Calculated. $\text{C}_{36} \text{H}_{22} \text{O}_{30} 8 \text{NO}_4$
Cotton found,	58.34	57.56	57.45
$\text{NO}_4 - \text{H}$,	—	not determined.	42.55
			100.00

Formula would be $\left\{ \frac{\text{H}_{22}}{\text{C}_{36} 8 \text{NO}_4} \right\} \text{O}_{30} = 846$.

100 of cotton produced 171.4; by calculation, 174.

Compound C.—Produced by $\left\{ \frac{\text{HO, NO}_2}{2 (\text{HIO, SO}_3)} \right\} + 4 \text{HO}$.

Like the preceding, this compound is very soluble in ether, but differs from it in being likewise perfectly soluble in glacial acetic acid. In this, as in the former compounds, the cotton fibre is quite uninjured. It is highly combustible rather than explosive, and burns with a slow jet of flame when rammed into a tube and ignited.

- I. 24.1 grains of cotton weighed, after first immersion, 38.26; after second immersion, 39.26; after third immersion, 39.53.
- II. By reduction, 9.94 grains of the compound gave 6.00 of cotton.

	By synthesis I.	By analysis. II.	By calculation. $\text{C}_{36} \text{H}_{23} \text{O}_{30} 7 \text{NO}_4$
Cotton found, ...	60.96	60.36	60.67
$\text{NO}_4 - \text{H}$,	—	not determined.	39.33
			100.00

Formula, $\left\{ \frac{\text{H}_{23}}{\text{C}_{36} 7 \text{NO}_4} \right\} \text{O}_3 = 801$.

100 of cotton produced 164.0: by calculation, 164.8.

Compound D.—The existence, composition, and identity of this compound with xyloidin, are inferred from the following reasons:—

1st. There is a compound lower than C, since $\frac{\text{HO, NO}_2}{2 (\text{HIO, SO}_3)} + 4 \text{HO}$ produces, by one immersion, an increase of only fifty-nine per cent., yet this product is perfectly soluble; if, however, C were the last, all products not attaining sixty-four per cent. in their amount of increase would contain unchanged cotton, and would be only partially soluble.

2nd. The product of the action of $\left\{ \frac{\text{HO, NO}_2}{2 (\text{HIO, SO}_3)} \right\} + 5 \text{HIO}$, in which the texture of the cotton is more or less destroyed, is only partially soluble in ether—cotton, apparently unchanged, remaining behind; it thus appears that the soluble portion is the lowest compound obtainable by the actions of mixed acids on cotton.

3rd. As the next number in the series, its composition would be $C_{30}\left\{\begin{smallmatrix} H_{24} \\ 6 NO_2 \end{smallmatrix}\right\}O_{30}$, which exactly corresponds with that assigned to xyloidin; and one hundred of cotton should yield 155.5. The soluble portion of these products further corresponds with xyloidin in giving an *opaque* film on drying, and in its solubility in glacial acetic acid. Although the xyloidins of woody fibre and starch agree in composition, they may be distinguished by the action of KS, HS, which reduces each to its proximate constituents, when the usual reaction with iodine may be obtained in the one case, but not in the other.

The modifications produced by the action of hot acids have not yet been examined; there is in these cases greater difficulty of avoiding loss in washing, in consequence of their disintegrated state, if immersed sufficiently long to obtain definite compounds. It is evident, however, that there are at least two, produced respectively by $\left\{\begin{smallmatrix} HIO, NO_2 \\ 2 (HIO, SO_3) \end{smallmatrix}\right\} + 3 HIO$, and $+ 4 HIO$, since the former becomes insoluble after drying, while the latter remains soluble. All the compounds soluble in ether give transparent films on drying, except D. The presence of this last-named compound is one of the causes of opacity on the drying of some collodions; the other causes are, water in the alcohol or ether, or the presence of acetic ether. All these compounds may be prepared with mixtures containing much larger proportions of sulphuric acid and water; but these have the disadvantage of rapidly dissolving the compounds if used warm.

While endeavoring to ascertain the state in which nitrogen exists in these compounds, HADOW was led to examine the action of caustic potassa on the highest compound, with which, as is well known, it produces a solution capable of reducing salts of silver to a mirror-like surface upon the vessel that contains them. The decomposition of gun-cotton by a solution of potassa takes place slowly at ordinary temperatures, but almost instantly on raising it to 160°. Each portion then immersed causes a considerable extrication of heat, by which the temperature is soon raised to the boiling point, and ammonia is evolved with effervescence. In making the solution for examination, the temperature was kept at 150°, to avoid the formation of secondary products. At this point the gun-cotton quietly disappears without effervescence, producing at last a dark viscid fluid. This was diluted, neutralized with acetic acid, and precipitated by neutral acetate of lead. The filtrate gave a further abundant precipitate with the basic acetate, from which it was at first concluded that there were two distinct acids present; this, however, was afterwards found to arise from the solubility of the plumbous deposit in the acetate of potassa that had been formed, from which solution the basic acetate again throws it down. The liquid filtered from both precipitates contained nitrite and nitrate of potassa. The lead precipitates, after thorough washing on a linen filter, were diffused through water, and decomposed by sulphide of hydrogen, during which process effervescence occurred, with escape of NO_2 , showing that, notwithstanding the washings the deposits had

undergone, they still retained a portion of nitrate. The brownish solution obtained was again precipitated by acetate of lead, washed, and decomposed as before, when a pale yellow, strongly-acid liquid was obtained, retaining the original reducing power upon the salts of silver unimpaired, and capable of rapidly decomposing carbonates with effervescence. Its power of forming crystalline salts was examined by slowly evaporating a solution of the compound on a slip of glass, and viewing it under a microscope. The ammonia-salt appearing to be the most promising, the liquid was neutralized with ammonia, and allowed to evaporate *in vacuo*. After some time, little tufts of prismatic crystals formed. On examination, however, these were found to be devoid of reducing power, and proved to be oxalate of ammonia. That the oxalic acid had not been formed by the subsequent processes was proved by detecting it in the original solution of gun-cotton in cold aqueous potassa. The liquid, freed from oxalic acid by nitrate of lime, was found to possess many of the characteristics of saccharic acid, such as its property of carrying down nitrites with its lead salts, and its reducing power on salts of silver, which is manifested in both cases on adding to the respective menstrua a portion of a solution of nitrate of silver, ammonia sufficient to cause a clear liquid, and subsequently caustic potassa, without which in either case no mirror-like deposit will take place even on boiling. In certain proportions the color of the reduced silver is identical. Like the neutral saccharates, the neutral salts of this acid, which might be termed pyroxylic acid until its identity with some other is proved, likewise give precipitates with salts of lime, baryta, and cadmium. The principal differences between the two acids are, that no crystalline acid pyroxalate of potassa could be obtained, the solution drying *in vacuo* to a gummy mass, whereas the acid saccharate is very easily crystallised; and that the saccharates of the above-mentioned bases are far more soluble in the heat than in the cold, and are visibly crystalline under the microscope; while the pyroxalates of lime and baryta are but slightly soluble on warming the liquid, and that of cadmium does not redissolve at all on the mere application of heat, though, like the saccharate, it is readily soluble in an excess of the salt of cadmium. The precipitates are likewise all amorphous, with the exception of the lime salt, which has the form of little nodules. HADOW could not further examine the properties of this acid, or obtain a compound with the certainty of its being sufficiently pure for analysis, in consequence of the want of crystalline form and the obstinacy with which a portion of coloring matter is retained.—HADOW.

COLLODION.—This substance, which is formed by dissolving gun-cotton in spirit, has of late years been extensively employed in the manner subsequently stated, under the uses of gun-cotton. The following are the best proportions for making it:—

Parts by weight.	
Prepared cotton,	8
Rectified ether,	125
Rectified alcohol,	8

Put the cotton with the ether into a well-stopped

bottle, and agitate the mixture for some minutes. Then add the alcohol by degrees, and continue to shake until the whole of the liquid acquires a sirupy consistence. It may be then passed through a cloth, the residue strongly pressed, and the liquid kept in a well-secured bottle.

Collodion thus prepared possesses remarkably adhesive properties. A piece of linen or cotton cloth covered with it, and made to adhere by evaporation to the palm of the hand, will support, after a few minutes, without yielding, a weight of from twenty to thirty pounds. Its adhesive power is so great, that the cloth will commonly be torn before it gives way. The collodion cannot be regarded as a perfect solution of the cotton. It contains, suspending and floating in it, a quantity of the vegetal fibre which has escaped the solvent action of the ether. The liquid portion may be separated from these fibres by a filter, but it is doubtful whether this is an advantage. In the evaporation of the liquid, these undissolved fibres, by felting with each other, appear to give a greater degree of tenacity and resistance to the exsiccated mass.

In the preparation of collodion it is indispensable to avoid the presence of *water*, as this renders it less adhesive; hence the ether, as well as the alcohol, should be pure and rectified. The parts to which the collodion is applied should be first thoroughly *dried*, and no water allowed to come in contact with them until all the ether is evaporated.

A method for the preparation of elastic collodion is given by LAURAS. He prefaces it as follows:—

The important improvement to be made in this compound, which hitherto has not been of very frequent application in therapeutics, consists in giving efficacy to it, and in preventing the sufferings produced by its application on any portion of the body, and principally on the articulations, which are much constricted after having been covered with it—an effect due to its want of suppleness and elasticity, and which the skin requires both for stretching and contracting.

By adopting the following formula, every inconvenience is obviated, collodion becomes easy of employment, and enables the patient to move without suffering pain:—

Sulphuric acid, of specific gravity 1.847, three hundred grammes; dry nitrate of potassa, two hundred grammes. These are both mixed together in a stone-ware or porcelain pot, and ten grammes of carded cotton added.

Leave in contact for twelve minutes; withdraw the cotton, wash it with cold water to remove the acid which it retains, and after two or three rinsings, immerse it in water containing thirty grammes of carbonate of potassa in solution in one hundred grammes of water; plunge it again into ordinary water, agitate well, and dry at a temperature of 77° to 86°.

The cotton thus prepared takes the name of Xyloidin, and may afterwards be mixed with the ether and the other substances which form it into elastic collodion.

Elastic Collodion.—Xyloidin eight grammes, ordinary ether one hundred and twenty-five grammes. Place in a wide-mouthed flask, and add alcohol of specific gravity .825 eight grammes. Agitate, and then make

a mixture composed of Venice turpentine two grammes; castor oil two grammes; white wax two grammes; ether six grammes. Heat together the first three substances, add the ether, and combine the two mixtures.

ADULTERATION.—Should it be desired to ascertain whether ordinary carded cotton has not been added to sophisticate the gun-cotton, it may be arrived at by the following micro-chemical process. A small portion of the cotton is impregnated with a solution of iodine, and a drop of sulphuric acid added, and then submitted to the lens; the gun-cotton is very feebly affected by this treatment, and retains the yellow coloration communicated by the iodine only slightly intensified after some time, whilst under the same treatment the fibres of ordinary cotton would quickly disintegrate, and partake of a lively violet hue. The intensity of the latter will be a comparative indication of the probable amount of the adulterants.

USES.—Many attempts have been made to apply gun-cotton to mining purposes on account of its enormous explosive force, and the small quantity of smoke which it produces; but the objections to its use are numerous, the most fatal one being its liability to spontaneous ignition.

Gun-cotton continues to be an object of great interest on account of its application to the beautiful art of photography. When the cotton is prepared in such a way as to burn slowly, it is not liable to spontaneous ignition, and it is in this state perfectly soluble in ether, which the more explosive cotton is not. If the ethereal solution be poured on the surface of cold water, a paper is produced, which is prepared for the use of the photographer. This paper is a very active electric, and is perfectly soluble in ether. Collodion has also been made use of in surgery, by applying the ethereal solution to a wound, when a thin delicate artificial skin is formed by it, which perfectly excludes the air.—*Encyclopaedia Britannica*.

GUNPOWDER.—*Poudre à canon*, French; *Schiesspulver*, German.—The article which bears this title is a singular mixture of nitrate of potassa—sulphur—sulphur, and charcoal, and is so well known for its remarkable properties by every one, that it is unnecessary to enter into a detailed exposition of it. Regarding its manufacture and the uses to which it is devoted, however, in a true light, its importance as an agent of power, which places it side by side with steam at the present day, cannot fail to render it an object of deep research and inquiry.

It might well be said that no other branch of industry has, during many years, decided the destinies of people so much as gunpowder. Sometimes favorable to the progress of civilization, powder offers to the miner and engineer a ready and sure means of breaking all obstacles which intercept their progress in their labors; sometimes, on occasions of festivity, it becomes in the hands of the artificer a symbol of joyful public rejoicings; and, finally, on occasions of civil strife and warfare, it turns out to be a sure instrument of death and massacre—spreading the devastating bullet or shell with an effect which lays nations of greatness and pomp level with the dust, and raises others to the dignity of empires.

The invention of gunpowder formed a grand epoch in the world's history. TOMLINSON ascribes it to BARTHOLO SCHWARTZ, a German monk and alchemist, and the date of the discovery is supposed to be about the year 1320. The prior claims of ROGER BACON, whatever they be, are, however, unquestionable, as this substance is described in his writings about the year 1270, or half a century before the supposed discovery by SCHWARTZ. But even BACON himself has as little title to the invention as his imagined rival; nor, indeed, when his own description of this then wonderful compound is examined, can it be perceived that he makes any claim to be the discoverer. On the contrary, he quotes it as a well-known substance in common use all over the world, for making squibs for the amusement of children—so pertinacious are vulgar errors. DUTENS attempts to show that the claim, which certainly does not belong to BACON, is removed to MAGNUS GRÆCUS, whose manuscript he quotes, and from which he presumes BACON derives his knowledge of the invention; although, by his own showing, BACON need not have consulted an obscure writing for an invention of general notoriety. In the same manuscript are contained directions for making a rocket, which are such as to prove that the nature of this firework was thoroughly understood. It is even remarkable that he recommends the charcoal of willow wood, which the moderns have found by experience to be amongst the best for such purposes.

Thus far the date of the origin of gunpowder has been traced, not only beyond BACON, but beyond this supposed predecessor, as he himself professes to be a compiler, not an author of the *Liber Ignium*, as he denominates his treatise. If, in attempting to ascend still higher, the evidence becomes more rare and illegible, there are still insuperable facts to prove that its antiquity is far greater, however impossible it may be to approximate to the date of the invention, much less to assign that which appears to be buried amongst the obscurities of oriental learning. The question of gunpowder as applied to artillery is a separate one; but there is abundant reason to believe that this compound was not only used in some form or other as an explosive and combustible substance, but that it was applied even to military purposes—it may be, in the shape of rockets or other fireworks, which, for objects of amusement at least, have been familiar to the Chinese beyond all record.

The earliest date to which the knowledge of gunpowder can be referred, in defect of a sufficiently remote acquaintance with oriental history, is 355 before Christ, although, from the very nature of this attestation, it follows that it was then not only known to the Eastern nations, but that it must have long been so, since, even at that early period, it was applied to warlike purposes. In the code of Hindoo laws, indeed, where it is mentioned, it is referred to an era which oriental antiquaries have considered as coincident with the time of MOSES. But the evidence to which more particular allusion is made, is found in a passage of the *Life of Apollonius Tyaneus* by PHILOSTRATUS, the purport of which is that ALEXANDER was unwilling to attack the Oxydrææ, who lived between the Hyphasis and the Ganges, be-

cause they were under the care of the gods, and overthrew their enemies with thunder and lightning which they shot from their walls. The same account is given of the repulses experienced in this country by HERCULES and BACCHUS.

The next of these early dates, in which also the evidence is imperfect, is 212 before Christ; but the establishment of the proof of the last would render this one more credible. In the defence of Syracuse by ARCHIMEDES, VITRUVIUS relates that one of his engines threw stones with a great noise—a description which does not apply to any of the mechanical artillery of the ancients. On a notice so superficial, however, much stress must not be laid, and here ends all the information respecting the earliest knowledge of gunpowder. It seems, however, so decidedly capable of being traced from the East, through the intervention of the Arabs, that there can be little doubt of its oriental origin, and of its being thence imported into Europe. Indeed, the military use of rockets in the armies of India ascends to a very remote period.

Of the earliest date at which it was known in China, their own evidence is defective; but UFFANO, an Italian author, affirms that not only gunpowder, but ordnance, was in use in that nation in the year 85, and that in his day cannon were remaining from the most ancient times in some of the maritime provinces, made both of iron and of brass. Hence some writers presume that the Chinese communicated the invention to the Indians; whilst it has also been said, but on no sufficient authority, that they themselves received it from Tartary—a nation respecting which little or nothing is known and in which one would not be inclined to look for an early acquaintance with the arts. This, however, refers to a date so late as 917; so that, if there is any dependence to be placed on the Indian and Chinese hypothesis, the Tartars must themselves have borrowed the invention from those to whom they are said to have lent it.

There is after this a long blank; and the first author on the subject is an Arabic writer, in the Escorial collection, whose work, bearing date 1249—about twenty years before the date of BACON's narrative—is translated by CASIRI. His description is such that it may apply both to rockets and to shells. In the former case, it only involves the knowledge of the detonating compound; the latter, were it proved, would show that they were also acquainted with the use of ordnance, although it is not impossible but that such projectiles might have been thrown by mechanical artillery.

As the invention of gunpowder has been popularly ascribed to BACON and to SCHWARTZ, so the use of ordnance has been referred to the time of the battle of Cressy—1346. To pass over the Chinese hypothesis on this part of the subject, it will be found that cannon were known at least as early as the year 1312. This is derived from the source quoted by CASIRI; from Arabian writers who in 1312 and 1323 describe the use of ordnance; whilst, if BARBOUR is to be trusted, EDWARD III. was also provided with some pieces of artillery in 1327, and Père DANIEL asserts that cannon were known to the French in 1338. This discussion need not be carried lower; though, in favor

of the oriental origin of the invention, it may be remarked, that artillery was much in use in the Mediterranean when it was still but little used elsewhere; as by the Venetians in 1380 against Genoa, and by ALPHONSO XI. in his wars with the Moors.—*Encyclopædia Britannica*:

In the prolegomena it was stated that gunpowder is a composition of definite quantities of sulphur, saltpetre, and charcoal. From time to time various experiments have been conducted with considerable care for the sake of determining the most convenient proportions of the foregoing substances; and, singularly enough, people have, in almost every instance, fallen back upon the recipes given by the most ancient writers upon the production of this article. The knowledge that powder owes its extraordinary effects to the sudden transformation of its solid constituents into permanent gases, the volume of which is enlarged by the temperature resulting from the chemical action producing this change, will at once lead to the conclusion, that all matters incapable of undergoing such a modification injure or depreciate, in proportion to their quantity, the quality and efficacy of the product. Hence it should always be the desire of the manufacturer to use the purest materials; and, to assist him in his business, they will be considered here.

MATERIALS.—The greatest care is requisite in the preparation of pure ingredients for the manufacture of gunpowder.

The principal saline impurity in saltpetre is chloride of sodium—common salt—which has a very injurious action upon gunpowder, causing it to absorb moisture, whereby its power is soon considerably weakened. Saltpetre containing more than a three-thousandth part of chlorides, is rejected as unfit for use.

The solubility of saltpetre at 212° is about fourteen times greater than it is at ordinary temperatures, while that of chloride of potassium is only about twice as great, and that of chloride of sodium is but slightly increased. If, therefore, a solution containing these three salts be concentrated, the greater quantities of the chlorides will be deposited as the water decreases, even before the nitrate of potassa exhibits any symptom of crystallizing out. This separation is effected in practice, by placing a perforated iron ladle or dish on the bottom of the boiler in which the solution is being concentrated. The chlorides, as they separate by the evaporation of the water, deposit upon the dish, and may from time to time be removed. When small needles of nitrate of potassa begin to appear, the menstruum is run off into the crystallizing cooler, from which tolerably pure saltpetre will be obtained, to be refined by a similar operation.

At Waltham Abbey the refining of saltpetre is effected by first decolorizing its solution by ebullition with newly-burnt charcoal, and then by repeated crystallization. Great care must be exercised in this process, which will be fully dwelt upon under POTASSA.

Sulphur, as employed for the manufacture of gunpowder, is generally in the sublimed state, or that known in common parlance as *flowers of sulphur*. These are obtained by conducting the vapor of sulphur into large chambers, the sides of which must

be kept cool. The sulphur condenses in the form of a fine crystalline lemon-yellow powder. When the sides of the chamber become heated, the sulphur fuses, becomes limpid, and trickles down to the base of the chamber. To prevent this, which, of course, would spoil the whole deposit of flowers, as soon as the walls of the chamber get too warm, the communication between the latter and the retort is closed, and another one opened, leading into a metal receiver; the sulphur is allowed to distil over into this until the first chamber has become sufficiently cool, and the flowers have been collected from its sides, when the vapors are again passed into it.

The sublimed sulphur sometimes requires washing, in order to free it from the sulphuric acid which is generally formed with it, and which is caused by the oxidation of the sulphurous vapors by means of the common air which pervades the condensing chamber previous to the commencement of the distillation of each charge.

It has been suggested that the sulphuric acid should be removed by allowing the sulphur to remain between damp cloths for some time previous to use.

Charcoal.—The third principal constituent of gunpowder is charcoal reduced to an impalpable state. This constituent demands no less attention in the selection than the other components; for much of the efficiency of the powder depends upon its possessing such qualities as experience has shown to be required. Even in the time of MAGNUS GRÆCUS, as already mentioned in the preceding historical notice, the charcoal of willow-wood was preferred, and experience has fully proved that the charcoal of the soft woods always produces the best results. Some time since, dogwood was adopted, as giving the most friable charcoal; but it has since been shown that the woods of the willow, poplar, black alder, and chestnut trees afford equally suitable products. The hard woods are invariably rejected, and with justice; though the presence in them of deleterious salts is not the only objection to their use.

Two considerations must not be overlooked in choosing a proper charcoal—namely, the nature of the wood, and the manner in which the carbonization of the same is conducted; and each demands the utmost circumspection in the manufacturer who is desirous of producing an article which will yield the greatest possible amount of force, and combine at the same time the quality of inflaming readily, as well as that of leaving the least quantity of residuary matter after its ignition.

There is no doubt, says the writer of the article GUNPOWDER in the *Encyclopædia Britannica*, that wood which contains carbonate of potassa or other deliquescent salts, is unfit for the purpose, and for obvious causes. This is the case in the oak, elm, fir, and other trees. But there is another reason for the badness of these kinds of charcoal, which is not so obvious, although it is evidently connected with their hardness. It appears to depend on the small proportion of hydrogen combined with the carbon in these charcoals, compared to that which exists in the produce of the softer woods. Even these can be reduced to the same state by subjecting them to higher temperatures. Thus the hydrogen is dissipated, the charcoal becoming

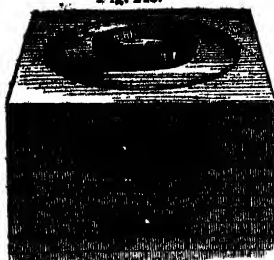
esters, to which reference will be made in their respective places. As the susceptibility of charcoal taking fire is a subject which, to those who are under the necessity

of storing it for some time in magazines, is highly interesting, it may be well to lay before the reader the procedure of VIOLETTE, for the estimation of the degree of heat at which charcoals enter spontaneously into combustion.

He adopted an apparatus similar to Fig. 246, in which A is a small flat plate-iron basin, floating upon a bath of tin or pewter, B, which is heated by a fire

at C. The pieces of charcoal, prepared in pellets 0.01 inches in length and 0.001 in thickness, were placed symmetrically in the basin, A, and the fire urged, thus increasing the heat of the tin bath, and, consequently, that of the small iron basin containing the cylinders of charcoal. The order of their inflammability was noted as each, in succession, gave indications of combustion by a luminous point appearing upon the circumference of the superior section, and which quickly enveloped the whole surface, and resulted in leaving only the ash. In the following table, the series in the column A show the order of the spontaneous ignition of the materials which had been thoroughly charred, whilst those in B represent the order with reference to brown charcoals, or such as retained a portion of their constituents, and, therefore, had only been but imperfectly made:—

Fig. 246.



SERIES A.

The order of the ignition of charcoal.	Temperature of the carbonization of charcoal.	
1	500°	518
2	270°	536
3	280	554
4	290	572
7	300	590
9	310	608
10	320	626
11	330	644
12	340	662
13	350	819
21	432	1873.6
22	1023	2372
23	1300	2732
24	1500	

SERIES B.

The order of the ignition of charcoal.	Temperature of the carbonization of charcoal.	
5	250°	452°
6	230	446
8	240	464
14	220	428
15	210	410
16	190	374
17	170	338
18	200	392
19	180	356
20	160	320

From the above, it may be inferred that charcoal, prepared at 500°, is the most liable to undergo spontaneous combustion. It is remarkable that the phenomena observed with regard to the brown or torrefied woods in the second column, before their entering into ignition of complete carbonization, was effected first, as indicated by the quantities of fumes which were disengaged from them; *id est*, they were converted into a charcoal such as that prepared at 500°. As soon as this condition was attained, they underwent spontaneous ignition. In the second place, it is easy to see that the inflammability of the charcoals decreases in proportion as the temperature of their preparation is more elevated. To make the examination more definite than the comparative but necessarily indeterminate one above mentioned, the following process was followed:—A porcelain crucible was selected, and about sixty grammes of saltpetre fused in it. The bulb of a mercurial thermometer immersed in it, showed that the melting occurred at 644°. Gradually pieces of the most inflammable charcoal, such as those prepared at 500°, were projected into the molten mass, and the crucible quickly inclosed to prevent cooling by radiation; on taking the cover off, the particles of charcoal were observed to be undergoing several commotions, but without taking fire, notwithstanding that, by increasing the heat only 1.8°, the matter burned. Hence it may be stated, that charcoal obtained at 500° ignites spontaneously at 645.8° or 646°. On increasing the temperature of the crucible and nitrate of potassa by

regular increments of heat, it was found that charcoals prepared at temperatures from—

500° to 536°	ignited at 680°
536 to 662	" 698

On raising the heat a little above 698°, the charcoal resulting at 819° ignited, but the other kinds, produced at a higher heat, refused to burn. As the thermometer ceased to indicate truly any higher heat, the bath had to be changed for one of pewter or tin. Having introduced the more incombustible charcoals, then gently raised the temperature with a charcoal fire till near the point of redness, they began to show the first signs of combustion.

In the annexed table the results are tabulated:—

The temperature at which charcoal has been carbonized.	The temperature at which the charcoal has taken fire.
260° = 500°	340° — 680°
270 = 518	340 to 360 — 680 to 698
280 = 536	
290 = 554	
300 = 572	
310 = 590	
320 = 608	360 to 370 — 698 to 716
330 = 626	
340 = 644	
350 = 662	
432 = 819	
1023 = 1873.6	600 to 800 — 112 to 1472
1250 = 2282	
1300 = 2372	
1500 = 2732	
Charcoals made at temperatures which fuse platinum,.....	
	1250 — 2280

The foregoing determinations possess a peculiar interest for the powder manufacturer, especially when it is understood that frequently charcoal, produced at temperatures between 500° and 662°, are employed for the purposes of sporting powder; the black kinds obtained at a higher heat, such as 819° or so, being reserved for the article in demand for the military and mining requirements. Now, since the first kind ignites spontaneously at 680°, the origin of the various explosions happening in powder mills may be easily traced. The increase of temperature by friction during the grinding, more especially when this is done by metallic bodies, often reaches the preceding degree, and, consequently, supplies the necessary conditions for inducing combustion in the mass; again, when placed in the state of fine powder in the recipients, it condenses so much air in its pores that the heat, which is a well-known result of such a condensation, is sometimes elevated to the above standard. Probably the compression referred to is not made without a chemical combination of a part of the oxygen with the hydrocarbon in the charcoal, and such slow combustion, gathering greater force as it progresses, may be in the end sufficiently active to ignite the whole mass.

VIOLETTE further examined several varieties of charcoal, all of which were prepared at 572° by both the foregoing methods; they inflamed between 680° and 716°, but in no case did they take fire at a lower heat than 680°. He observed that the charcoals from light woods generally ignited a little before the product from the harder kinds, with the exception of one, which is remarkable, namely, the charred product of the fungoid excrescence of the willow tree (*agaric de saule*). The latter was observed to take fire in one instance at a temperature so low as 572°, and in every experiment at 608°. Hence it is the most inflammable of all species of charcoal; and, as the above-named investigator remarks, had it been prepared at 500° instead of at 572°, doubtless its spontaneous combustion would take place at a lower temperature than even that given. It may well be inquired to what may this peculiarity be attributed? and, doubtless, as VIOLETTE suggests, the organic molecular state of the substance might exercise some influence whereby its rapid ignition is induced.

To sum up these results, it will be seen—

1. That the most inflammable of all wood charcoals (*agaric de saule*) takes place at 572°.

2. That the charcoals from different kinds of wood, when prepared at a constant heat of 572°, spontaneously ignite between 698° and 734°, according to the nature of the wood producing them; but that the product from the lighter burns quicker than that of the denser woods.

3. That charcoals from the same wood, only prepared at increasing temperatures, spontaneously undergo combustion at very unequal degrees of heat, as shown in the table, page 50, *ante*.

After attentively considering these results, very little doubt will remain as to the best means of carbonizing the wood. To a certainty the temperature of the charcoal, as prepared by most of the methods indicated under the charring of wood, vol. ii., *et seq.*, and also under ACETIC ACID, exceeds the limits laid down by

VIOLETTE; and, therefore, it follows that the combustion of a powder made by such materials will require a greater amount of caloric to induce its decomposition than if the charring heat was less. Where the process by superheated steam or gases is not adopted, evidently the choice should be decided in favor of that method which furnishes the charcoal at the lowest degree of heat. There are three methods in ordinary use by which the charcoal for the powder manufacturer is prepared, namely, the pit, the furnace, and the closed retort. When pits are selected, they are made smaller than those described in the foregoing articles, and the walls and sides, together with the apertures for the introduction of air, are constructed with more care; the wood is also arranged in them with greater caution, and the combustion watched so that, during the operation, the whole may be completely acted upon, and no half-burned material left. In the general particulars, however, no difference exists between the methods already alluded to and this, so that it will be needless to repeat the description. The product amounts to sixteen or seventeen per cent. of the wood. If the carbonization is effected in furnaces, the quantity of the product will not be so large; besides the consumption of fuel will be greater than in the preceding case. In England, however, the charcoal obtained by the distillatory process in closed retorts is always preferred, although a considerable expenditure of fuel is occasioned in heating the vessels. The apparatus described at vol. i., page 17, is the same as used in this operation. When the process of carbonization is coming to a close, the pipe connecting the cylinder with the pyroligneous-acid receiver must be closed, and very free egress must be allowed for the volatile matter; otherwise the charcoal is liable to injury by the deposition of a fuliginous varnish, and even by its reception of, and saturation with, condensable matter.

TOMLINSON, who writes the excellent article GUNPOWDER in the *Encyclopædia Britannica*, is inclined to consider this preference for distilled charcoal a mistake of the *causa pro non causa*. Pit charcoal, being made in coppice woods, is always the produce of oak; and it is probable that this wood, if charred in close vessels, would be even worse than it is now. There is more danger of overheating in the retort than in the pit, while the wood is not better burned; and hence, by a careless management of the process, even the charcoal of willow and alder may be rendered as bad as that of oak. Considering these various circumstances, charcoal requires to be submitted to three tests. It ought to act as little as possible mechanically, even on copper; no salts should be extracted from it by treating it with boiling distilled water; and it ought to give out no smoke when heated. The latter test is indicative of its being thoroughly burned.

The selected wood, whatever its variety, should always be cut when in sap, and never when dead. Wood of five or six years' growth is better suited for the manufacture of the charcoal than older kinds; for, generally, the latter contains more mineral matters, and, consequently, less carbon than the former; and the most convenient size is branches from three-quarters to an inch in diameter.

The charcoal, says Dr. URE, is considered by the scientific manufacturers to be the ingredient most influential, by its fluctuating qualities, upon the composition of gunpowder; and, therefore, it ought always to be prepared under vigilant and skilful superintendence. If it has been kept for some time, or quenched at first with water, it is unsuitable for the purpose. Charcoal extinguished in a close vessel by exclusion of air, and afterwards by exposure to the atmosphere, absorbs only from three to four per cent. of moisture, while red-hot charcoal quenched with water may lose, by drying, twenty-nine per cent. When the latter sort is used for gunpowder, a deduction of weight must be made for the water present. Charcoal, however, which has remained long impregnated with moisture, constitutes a most detrimental ingredient of gunpowder.

Before entering upon the description of the process for compounding the substances which constitute gunpowder, it may be well to give a few additional facts relative to the circumstances which affect the mutual decomposition of those bodies as they exist in this article, and render the phenomena of its explosion more easy of comprehension. Already some experiments of PROUST have been adduced, which elicit comparative data of the explosiveness of certain varieties of charcoal when mixed intimately with saltpetre; but they do not afford any real knowledge as to the degree of heat required to bring about such a metamorphosis, although they indicate that some kinds of charcoal form more inflammable mixtures with nitrate of potassa than others. The investigation of VIOLETTE upon the temperature at which charcoal decomposes this agent, is much more definite, and consequently interesting. He found that the degree of caloric which occasions the combustion of charcoal in the air, is much lower than what is necessary to cause the carbonaceous matter to decompose the oxidising agent which is incorporated with it in the powder. To determine this, he proceeded thus:—In a small porcelain crucible, heated by a carcel-lamp, which allowed the temperature to be easily regulated, nitrate of potassa was melted and maintained at 680° , being the degree at which the charcoals burned in the air. Into this bath a small cylinder of charcoal appended to a platinum wire, or glass rod, is plunged, so that it is all submerged; although numerous bubbles of gas were disengaged, yet the carbonaceous mass did not take fire at this temperature. By raising the heat gradually to 716° , and, trying the experiment at this stage, the effect was still negative, but ultimately it deflagrated after the bath had been raised to a higher degree of heat. The fusion of lead and zinc showed the thermometric effect to be above 680° ; but it being incapable of melting antimony, it was evident that the heat had not reached 819° , the fusing point of the latter metal. It may be concluded, therefore, that all charcoals prepared between 500° and under to 819° decompose nitrate of potassa at 752° , but that such as are obtained between 1832° and 2732° are not affected at the preceding, nor at much higher heat, since they do not even burn upon the surface of the bath.

The same chemist determined the degree of heat at which sulphur decomposes nitrate of potassa in an

equally ingenious way. He found that when sulphur was thrown upon the surface of the bath of fused salt, raised to the temperature of 680° , it floated about, melted, and inflamed; the combination, however, was with the oxygen of the air, and none of the saltpetre had been acted upon. A similar result was arrived at when the bath was at 752° , or even a few degrees higher; but when it had attained 819° , the fusing point of antimony, deflagration occurred by the decomposition of the potassa salt, and the evolution of a brilliant white light and a considerable quantity of gases. In the latter experiments it was necessary that the sulphur, like the charcoal in the last-mentioned examination, should be immersed in the fluid bath. To do this, VIOLETTE had a platinum crucible about the size of a pea constructed, and to this he appended a platinum wire, which might serve as a holder to it when immersed, mouth-under, in the bath. When 0.1 grain of sulphur was melted in this tiny vessel, and plunged into the bath in the manner shown in the annexed diagram, the effect was observed with considerable accuracy. Until the heat had reached the decomposing degree, the sulphur was observed to ascend in bubbles of colorless vapor through the transparent bath, and burst into a beautiful blue flame. As soon as the inflammation of the sulphur commenced within the fused saltpetre, the white light traversed the whole mass with the effect already detailed.

Fig. 247.



An observation of VIOLETTE's is worthy of notice here. During his examinations of the combustion of sulphur in nitrate of potassa, he tried at what temperature this element burns in the air, but found that the limits which are stated with reference to it in chemical treatises differed, both from one another as well as from his results. DUMAS gives the combustion of sulphur in air as taking place at 302° ; DALTON states that the heat is 500° , and THOMSON, 561° ; but VIOLETTE affirms the melting point to be exactly 480° . His experiments were performed on the surface of a bath of tin; contact of the sulphur and metal being avoided by placing it upon a thin pellicle of glass, and floating the latter upon the hot metal.

It was also observed that by sprinkling a little sulphur upon charcoal thrown upon the surface of the heated bath, ignition took place under the degree at which the most combustible charcoal kindles, *per se*. This occurs on account of the heat developed by the combustion of the sulphur at 480° , and which brings the charcoal to the state of redness, and consequently at which, when air is supplied, it rapidly inflames.

PROPORTIONS OF THE INGREDIENTS.—The progress of improvement in determining the proportions of the constituents of gunpowder, has been very gradual. In this country, a long period elapsed before the present state of perfection was attained; but this cannot well be wondered at, when one takes into consideration the ignorance which existed even up to the commencement of the present century, not only with regard to the theoretical laws of science, but also in respect of the properties of bodies purely chemical.

Such compounds as saltpetre, sulphur, and charcoal

in equal proportions were scarcely fit for squibs, much less for the purpose of projecting shot. Again, one finds such mixtures as saltpetre twelve parts, with three each of charcoal and sulphur; twenty-seven of nitrate of potassa to three of each of the other ingredients; saltpetre forty-eight, sulphur seven, and charcoal three parts; with many others which now-a-days appear equally ridiculous. At no very distant period, the French compositions were, saltpetre fifty, sulphur sixteen, charcoal thirty-four parts; saltpetre sixty-seven, sulphur thirteen, charcoal twenty; and again, saltpetre eighty-four, sulphur eight, and charcoal eight parts.

BAPTISTA PORTA was one of the first who endeavored to ascertain the best relative quantities of the constituents, and his proportions, obtained in the year 1515, approached very nearly those now employed in France. The deductions of GUYTON MORVEAU, BEAUMÉ, CHAPTAL, PROUST, and RIFFAULT, are represented below:—

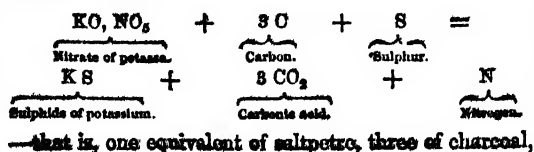
DUMAS gives the proportions, saltpetre 75, sulphur 12.5, and charcoal 12.5, as the most ancient known, and states, that however these proportions have been deviated from, either from pressing circumstances of time or place, the powder manufacturer had in the end to fall back upon the above mixture as offering the best composition. This seems to be the case, since the researches of the several original chemists who have taken up the question give mixtures closely approximating to those numbers, as may be seen from the annexed table of the mixtures recommended by them.

	Saltetre.	Sulphur.	Charcoal.
Guyton Morveau,	76	9	15
" "	77	7	17
" "	80	5	15
Beaumé,	80	5	15
Chaptal,	77	9	14
Proust,	78	9	13

To these may be added the following:—

	Saltetre.	Sulphur.	Charcoal.
Powder of Bâle,	75.0	10	14
" Grenelle,	76.0	12	12
" Riffault,	77.5	7.5	15
" Bouchet,	77.0	9.5	13.5

Of the latter class, that of Bâle is accounted the best for military and general warlike purposes; but, notwithstanding the superiority it possesses when recently prepared, if the compound has to be retained for a long time in magazines or to endure long transport, it does not answer so well as the old proportions above referred to. Theoretically considered, this is, granting that all the materials possessed absolute purity, the best composition; for if the nature of decomposition of powder be attended to, and the products of the combustion examined, it will appear that only carbonic acid, nitrogen, and an alkaline sulphide are produced. Hence it may be reasonably inferred that the chemical symbol corresponding with this decomposition, admitting of no loss, would be,—



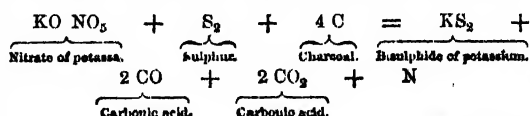
and one of sulphur, by being made into a powder, affords one equivalent of sulphide of potassium, three of carbonic acid, and one of nitrogen. Calculating from these data the percentage quantity of each to be taken, the annexed results are obtained:—

	Theoretically.	Practically
1 Eq. of nitrate of potassa,	101	74.81 = 75.0
1 Eq. of sulphur,	16	11.85 = 12.5
3 Eqs. of carbon,	18	13.34 = 12.5
	135	100.00 100.00

The difference between these numbers is so minute as to be worth noticing, even were nothing else to be taken into account; but as shown by the analysis of several charcoals, as given under FUEL, there is always more or less hydrogen present, which concurs to make the combination more complete, and in accordance with theoretical results. Another instance of the accuracy of the quantities taken for the preparation of another quality of powder, is the variety generally used for mining and blasting purposes. The proportions taken for this are:—

Saltetre, 65; sulphur, 20; charcoal, 15;

Numbers which closely correspond with the formula,—

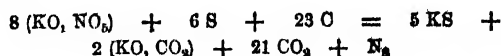


	Centrally.
1 Eq. of nitrate of potassa,	101 = 64.33
2 Eqs. of sulphur,	32 = 20.44
4 Eqs. of charcoal,	24 = 15.23
	157 100.00

Sporting powder is another of these compositions which may be reduced to the simplicity and certainty of a chemical formula. The usual quantities of the materials taken in this case are:—

Saltetre, 78; sulphur, 10; charcoal, 12;

Numbers which may be expressed by equation, although this is not so simple as the preceding, owing to there being a slight excess of oxygen over and above what the charcoal combines with, and the amount of sulphur used being incapable of retaining all the potassium in the state of sulphide. This will be seen from the formula,—



That is, eight equivalents of saltpetre, six of sulphur, and twenty-three of carbon, afford five equivalents of sulphide of potassium, two of carbonate of potassa, and twenty-one of carbonic acid and eight of nitrogen. The truth of the formula is proved in a very striking manner by the following calculation:—

	Centrally calculated formula.	Given mixture.
8 Eqs. of nitrate of potassa, ..	808	77.54
6 Eqs. of sulphur,	96	9.21
23 Eqs. of charcoal—carbon, ..	188	13.25
	1092	100.00 100

The analogy in both the foregoing instances is suffi-

cient to show that the powder-maker has in compounding his mixtures an unfailing guide, by following which he cannot get far wrong. A little difference is occasioned in the foregoing, in the quantity of the calculated charcoal especially; but the explanation of the presence of hydrogen, which takes up such a large quantity of oxygen from the nitrate of potassa during the explosion of the powder, accounts for this. Indeed, were it not for this excess of hydrogen which makes up for the assumed amount of carbon in the charcoal, it would be difficult to reduce the quantities of real matter in the substances within the expression of a simple formula. Analyses show that the quantity of carbon in the charcoals which are usually incorporated, varies from sixty-eight to ninety per cent., and it is evident that when numerical quantities of the ingredients, such as ex-

pressed above for the manufacture of the powder, are strictly adhered to, serious differences occur in the quality of the article, according as the charcoal is more or less rich in carbon. To adhere, therefore, to the strict proportions indicated by the numbers laid down, and which assume that the materials are pure, it becomes absolutely necessary to determine the amount of carbon in the charcoal, and regulate the quantity according to such an estimation; otherwise it is not at all surprising that two powders prepared exactly according to any given recipe, but with different materials of unknown qualities, should have very unequal effect when exploded.

The following table shows the proportion of the ingredients used by the powder-makers of different nations:—

Countries.	Artillery Powder.			Musket Powder.			Sporting Powder.		
	Saltpetre.	Sulphur.	Charcoal.	Saltpetre.	Sulphur.	Charcoal.	Saltpetre.	Sulphur.	Charcoal.
England—Government Mills, Waltham Abbey,.....	75·0	10·0	15·0	76·5	9·00	14·5	79·7	7·8	12·5
	75·0	8·0	17·0	78·0	9·25	12·75	78·0	8·5	13·5
	76·0	9·5	14·5	78·0	8·5	13·5	78·0	8·0	14·0
Austria,.....	70·0	16·0	17·0	72·0	16·0	17·0	.....	.....	.....
	76·0	11·0	13·0	75·5	11·3	13·2	80·0	12·0	14·0
France,.....	75·0	12·5	12·5	75·0	12·5	12·5	78·0	10·0	12·0
United States,.....	75·0	12·5	12·5	.....	.....	.....	.....	.....	.....
	71·0	11·5	17·5	80·0	8·7	11·3	80·0	8·0	12·0
Russia,.....	75·0	10·0	15·0						
Prussia,.....	75·0	11·5	13·5	.....	.....	.....	.....	.....	.....
Spain,.....	76·5	10·8	12·7	.....	.....	.....	.....	.....	.....
Haarbourg,.....	72·0	14·0	14·0	.....	.....	.....	.....	.....	.....
Hanover,.....	71·2	10·8	18·0	.....	.....	.....	.....	.....	.....
Hesse—Grand Duchy,.....	74·4	10·6	15·0	73·7	10·7	15·6	.....	.....	.....
“ Electorate,.....	73·4	13·3	13·3	.....	.....	.....	.....	.....	.....
Holland,.....	70·0	14·0	16·0	.....	.....	.....	.....	.....	.....
Italy—Milan,.....	76·0	12·0	12·0	.....	.....	.....	.....	.....	.....
Portugal,.....	75·7	10·7	13·6	.....	.....	.....	.....	.....	.....
Saxony,.....	75·5	8·2	16·3	76·5	10·5	13·0	.....	.....	.....
Sweden,.....	75·0	9·0	16·0	.....	.....	.....	.....	.....	.....
Wurtemberg,.....	75·0	12·0	13·0	74·5	10·7	14·8	.....	.....	.....
Baden,.....	76·0	10·0	14·0	76·0	10·0	14·0	76·0	10·0	14·0
China,.....	61·5	15·5	23·0	.....	.....	.....	.....	.....	.....
	75·7	9·9	14·4	.....	.....	.....	.....	.....	.....

Several other proportions are in use in the countries specified above, which, to some extent, vary from those given. It is reasonable to suppose that in choosing the foregoing numbers, the manufacturers of the several countries mentioned have conscientiously selected the numbers given as affording the best results; still, as there seems to be no tabulation of the composition of the materials, more especially of the charcoal, the Editor believes that a considerable amount of empiricism must be connected with it; at all events, the variation in the proportions must be attributed to the inequalities in composition of the varieties used: for, had each sought the most appropriate mixture, and employed charcoal of a known per-centage of carbon, doubtless, instead of the many variations, one invariable proportion would be adhered to by all, and a close analogy in the explosive force of the powder could be calculated upon. The species of powder which is used for mining and similar purposes vary in composition from the kinds used for the military and for sporting; it has a much larger proportion of charcoal than the latter, and consequently it is less expensive. From the example given in the preceding of the parts of such powder centai-

mally, and the exposition of its decomposition by a rational formula, this is shown to be the case: besides, the products of the explosion contain, with carbonic acid, a large volume of carbonic oxide. As will be shown further on, the volume of gases which such a powder affords is larger than what results from the shooting powder; but still the propulsive effect is less than with the latter.

With reference to the study required to insure the production of the best possible compound, and to find a general recipe, VIOLETTE submits a suggestion to which the Editor subscribes, as it would contribute more than anything else to register the quality of the various powders and excite inquiry; namely, that a register of the propelling powder should be kept annually, and such submitted to a competent party for consideration. As to the indications in the targets, however, they are liable to be affected by the nature of the piece; and, in fact, the powder itself, when made from precisely the same ingredients by two neighbouring establishments, varies in some measure, in consequence of the dissimilar manipulations.

To ascertain how far the powders prepared from

variable quantities of materials of the same centesimal composition differ in their ballistic effect, VIOLETTE prepared a number of samples of fowling powder, each weighing about twenty kilogrammes, forty-four pounds, and submitted them to the test. The following are the results:—

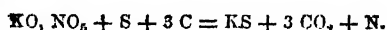
No.	Per-centage composition of materials.			Amount of carbon in one hundred parts of charcoal.	Speed of the ball by the ballistic pendulum.
	Saltpetre.	Sulphur	Charcoal.		
1.	78	10	12	68	357
2.	72	9	19	68	350
3.	72	10	18	68	355
4.	71	10	19	68	361
5.	71	11	18	68	363
6.	71	9	20	68	370
7.	71	11	18	85	337

In this table No. 1 is the regular proportion, and the speed of the ball with such, supposing all the powder to be consumed, would be, according to the usual rule, three hundred and fifty metres. It is surprising to observe that No. 6 in the above collection, in which the saltpetre is diminished by eight parts, and the sulphur by one, and the charcoal increased by eight, is a superior powder to No. 1. No. 5 also constitutes a very good powder, but its quality would be considerably deteriorated by using, instead of the charcoal containing only sixty-eight per cent. of carbon, one yielding eighty-five per cent., as shown in the last. This forms a striking example of the way in which an inequality in the per-centage of carbon in the powder affects it.

The chief qualities which a good gunpowder ought to possess, are ready inflammability, complete decomposition of its constituents, the production of the largest possible volume of elastic gases, and finally, that of affording only the smallest possible amount of residue, and even that should be of such a nature as not to injure the gun.

Inflammability of Powder.—From what has been stated in the preceding pages relative to the degrees of heat required to decompose the constituents of powder, a good inference may be drawn as to the degree of heat at which powder will take fire.

However, if a small quantity of powder be slowly heated, and the temperature be gradually raised, it will be observed that the sulphur, which is the most inflammable constituent, will begin to burn with a blueish flame at 482°, or thereabouts; and the heat developed in this partial combustion brings the other constituents into that state at which the nitrate of potassa is decomposed by the charcoal, whilst the remainder of the sulphur adds to the effect by combining with the metal of the oxidising agent, thus—



To ascertain whether the powders, as usually manufactured, actually do ignite at the burning point of sulphur, VIOLETTE made some examinations by placing portions of the powder to be tested on the surface of a bath of tin, in which the bulb of a thermometer was immersed, the whole being heated by a small carcel-lamp: the following results were obtained—

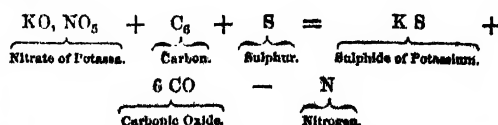
No.	Species of Powder.	Temperature which produced deflagration.	
		Powder in angular grains.	Pulverized powder.
1.	Blasting powder,	518°	509°
2.	War “	528.5	510.5
3.	Sporting “ fine,	536	514.8
4.	do. “ extra-fine,	608	518.0

Of these No. 1 was made with black charcoal, and No. 4 with brown or torrefied charcoal, the inflammability of which takes place at a much lower degree of heat than the first; still it is a matter of some surprise to find that the former, in the shape of powder, burns at a lower heat, excepting the variation in the quantity of sulphur present in them may influence the deflagration. This element is present in the four samples in the following ratio, namely, 20, 12.5, 10, and 9 per cent.; the most combustible of the powders having the largest amount of sulphur, which, of all the elements, is the most ready to enter into ignition. It may likewise be remarked that the size of the grain influences, in some measure, the temperature at which the powder burns.

Balistic or Propulsive Effect of Gunpowder.—The force with which a ball is projected, or a rock fractured, is, as may be easily understood, in proportion to the volume of gases which is produced when gunpowder or any other modification of this article is deflagrated. In case of gunpowder, these gases are principally carbonic acid and nitrogen; and where mining powder is operated upon, carbonic acid is likewise a product. But besides these it is found that small quantities of many other products are invariably formed, among which may be mentioned carbonic oxide, sulphurous acid, sulphide of hydrogen, bisulphide of carbon, carbonate of potassa, cyanide, and sulphocyanide of potassium and aqueous vapor. The most important products of a careful and complete combustion, on a small scale, of powder of the above composition, have, however, been found to correspond pretty closely to the above theoretical expression.

The gases disengaged in the combustion of this powder, would comprise, at 32°, a volume three hundred and twenty-nine times as great as that occupied by the powder. The force exerted by the evolution of these gases is, however, mainly dependent upon their enormous expansion at the instant of the explosion, by the heat evolved in the action; for it is calculated that one volume of powder of the above composition yields, at the moment of ignition, at least two thousand times its volume of gas.

If gunpowder contain more carbon in proportion to the nitrate of potassa than the quantity above stated, a proportionate amount of carbonic oxide is produced in its explosion; thus if six instead of three equivalents of carbon be employed to one equivalent of saltpetre, the whole of the oxygen contained in the latter would theoretically be eliminated as carbonic oxide on the decomposition of the powder, as the following equation shows:—



Now, since the space occupied by equal equivalents of carbonic oxide and carbonic acid is the same, it is evident that a much larger volume of gas would be evolved—calculated for a temperature of 32°, and ordinary barometric pressure—from the gunpowder which contained the larger amount of charcoal. But it must be borne in mind that the amount of heat disengaged in the production of carbonic oxide is far less than that generated when carbonic acid is produced, and that consequently the powder which contains the minimum quantity of charcoal will yield, at the instant of explosion, by far the greatest bulk of gas. That this expansion of the gas by heat is of the utmost importance, is very evident from what has been already stated. The fact that the temperature evolved by the combustion of gunpowder, estimated at 2192°, has been found to be sufficiently intense to fuse gold, silver, and other metals, and that the expansion of gases increases greatly with an augmentation of temperature—two hundred volumes of gas raised to 2428° occupying the same bulk as three hundred volumes, which are only heated to 1466·6°—render the value of a slight elevation of temperature at the moment of explosion still more apparent.

As it is difficult, nay impossible, under ordinary circumstances, to gain a knowledge of the quality of powder by any method involving the necessity of measuring the gases and caloric evolved, a more direct course of experiments is resorted to. This method was founded by PROUST partly upon the duration of the combustion, coupled with the volume of gases which were eliminated. The methods of operations employed were the same as those already described with regard to the estimation of the time required to deflagrate charcoal and nitre, *et cetera*. The following were his results:—

No. .	Saltpetra.	Sulphur.	Charcoal.	Time of combustion in seconds.	Products in gas in cubic inches.
1.	60	10	15	8	91
2.	60	10	12	6	91
3.	60	10	10	6	91
4.	60	10	8	7	88

It is presumed that these determinations, however, leave much to be required, not only in the accuracy of the determinations, but with respect to practical application.

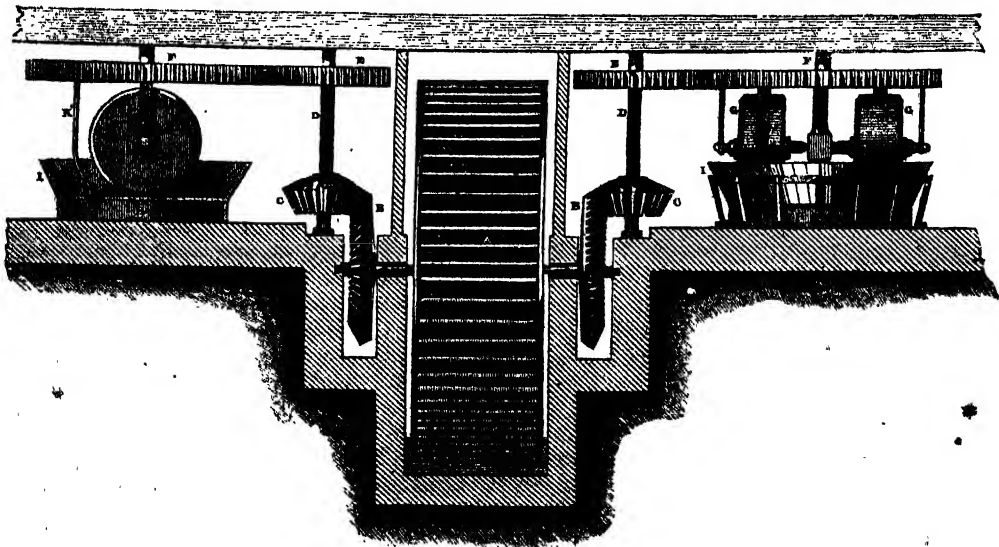
TOMLINSON adopted another method, which, on the whole, is more applicable to practice—namely, the determination of the altitude of rockets, and which he describes as being less liable to disturbances from collateral causes than any practice with pieces of ordnance. The rockets were of compound dimensions, and were all made with the same proportions and driven with the same hand, so as to insure all possible uniformity; the only variation being in the nature of the charcoal. The vertical elevations were taken by two quadrants at the same time, and all the flights that deviated from the perpendicular were rejected. The mean vertical ascent made with a great number of these, in which the charcoal was from the willow, alder, and dogwood, was four hundred and eighty yards; but between these three charcoals the difference was so great as to give various results, which may be represented by the following numbers:—

Dogwood charcoal,.....	515, 550, 525
Willow ".....	470, 480, 490
Alder ".....	455, 460, 470

To the methods in use, and recognized by the military and powder manufacturers generally, reference will be made further on.

Upon comparing the composition of the powders prepared in different countries for fire-arms, they will be found to agree more or less closely with the cen-

Fig. 218



testinal composition as above expressed. It must be remembered, however, that the proportions have been arrived at by experience, in most cases long before any

theory concerning the chemical composition or action of powder was advanced. In some cases the deviations from the theoretical numbers may be readily ex-

plained. Thus in the manufacture of the Waltham Abbey powder, a slight excess of charcoal is always employed in order to allow for the small quantity of inorganic matter always associated with carbon in that form; while the proportion of sulphur is reduced as much as is compatible with the production of a strong powder, in consequence of the injurious action of that substance, and even of sulphides in the presence of moisture, upon metal.—*Abel and Bloxam.*

MANUFACTURE.—The merely mechanical part of the manufacture of gunpowder is essentially the same in principle, and differs only to an immaterial extent in detail, whether in the various gunpowder mills in Great Britain, or in those of her continental neighbors. The Editor will trace the method of manufacturing gunpowder as it is employed at the Government Mills, Waltham Abbey:—

In the first place, it may be stated that water is the motive power in most gunpowder mills; the necessity of the presence of fire when steam is made use of is attended with so much danger, that this agent has not yet been introduced for the purpose.

The gunpowder mill is represented in Fig. 248, where A is the water-wheel; B B, two vertical bevel wheels fixed upon the axis of the great wheel, and working into C C, which turn the shafts, D D; E E are two horizontal spur-wheels, fixed to the upper part of D D, and driving the large wheels, F F. To the shafts of these latter are fixed the runners, G G, which traverse the bed-stone, H H; I I are the curbs surrounding the bed-stone to prevent the powder from falling off; K is the scraper.—*Ure.*

The materials, having been pulverized in the mill, are apportioned out, the following being the proportions at Waltham Abbey:—

	Pounds	Ounces.	Drachms.
Saltpetre,	31	8	0
Charcoal,	6	4	13
Sulphur,	4	3	3
	42	0	0

This quantity of the ingredients, termed a *charge*, is placed in the mixing apparatus, which consists of a wooden cylinder traversed in its centre by an octagonal shaft provided with several fan-like arms. Both the shaft and cylinder are kept in motion, but in different directions. This latter arrangement so facilitates the commingling, that the homogeneous powder is ready for removal and further manipulation in from five to ten minutes, when it is transferred to bags which are pressed, and the mouths of which are firmly secured, in order to prevent the disunion or separation of the ingredients in the order of their density, during the transport to the incorporating mill. It is evident that if the charges were too lightly packed, the ingredients would be liable to be separated in a greater or less degree, the saltpetre finding its way to the bottom, while the sulphur and charcoal would form layers above; the latter, from its light, pulverulent state escaping, in the form of dust, between the fibres of the cloth of which the bag is formed.

The next process is the *incorporation*. The mixture is spread out upon the bed of the mill, distilled water is added to insure the intimate cohesion of the par-

ticles—the amount of water required varying much according to the temperature and other atmospheric conditions, as also in proportion to the degree of comminution of the constituents—and the whole is again submitted to the action of the mill, to insure the uniform pressure and bruising of the rollers; but in this case the motion is less rapid than during the grinding of the ingredients. A great degree of caution must be exercised to prevent the intervention of any hard or silicious matters. The requisite amount of moisture must be maintained during the operation, and for this purpose water is slowly added at suitable intervals, till the incorporation is complete, which is generally the case at the expiration of from three to four hours.

The homogeneous compound has now the properties of gunpowder; it indurates in a very short period, forming hard cakes, which should possess a dark greyish-black hue, and free from specks of any kind; it is now termed *mill-cake*. When this has lost much of its moisture, but before it becomes completely dry, it is passed between corrugated or channeled cylinders, termed the *breaking-down mill*, and is then submitted, between copper plates, placed in strong boxes, to hydraulic pressure of about one hundred and twenty tons per square foot, after which it is known as *press-cake*; it is now greatly altered in appearance, and apparently resembles slate, being in dense blackish cakes, about half an inch in thickness. This powerful pressure is productive of several advantages:—

1. The powder has a greatly augmented density, and a given quantity of it will evolve, on combustion, a far larger volume of gas, than an equal bulk of powder which has only received the pressure of the incorporating mill.

2. From the increased hardness of the powder, it better resists atmospheric action; and besides this, it is not so liable to loss from *dusting*, caused by friction, during its transport.

The powder has now to be granulated. The machine employed for this purpose at Waltham Abbey consists of a pair of metal cylinders, provided with large teeth, upon which, while in revolution, the press-cake is allowed to fall in fragments; by this means it is reduced to grains of various sizes. As these pass from the cylinders or rollers, they are submitted successively to the action of three sieves of graduated fineness, placed one over the other, and jolting or working continually backward and forward. The powder retained by the first sieve is subjected to the action of a second pair of rollers with finer teeth, whence it again passes to, and is sifted by, the upper screen. The portions still too coarse to pass through, are reduced by a third still finer set of rollers. The powder manufactured at Waltham Abbey is distinguished as L. G., or *large-grain*, F. G., or *fine-grain*, and *meal-powder*, or dust. The first variety is retained by the second sieve; the lowest sieve reserves the fine grain; the dust, or meal-powder, collects beneath. Each kind is collected, as it falls from the screen, in boxes running on wheels and rails.

Various other contrivances belong to this effective machine to obviate the necessity for the attendance of

workmen, and, consequently, to prevent their injury should any accident occur.

The granulated powder is next freed from dust by running it through *reels*, similar to the bolter employed in dressing flour—encased in boxes, and covered with canvas or with silk, of about fifty-six meshes to the inch, according as large or fine-grain powder is introduced.

The finest powder is now *glazed* by subjecting it, in a slightly moist state, to rotary motion in barrels or drums, similar to the mixing machine already noticed. The velocity of rotation must be just sufficient to cause the grains only to roll over each other slowly, and thus become polished by attrition. Blasting-powder is occasionally glazed with graphite.

The gunpowder is finally dried, which is now generally done by means of steam-heat; sometimes it is effected by transmitting a current of air, previously heated in another chamber to from 130° to 150°, over the powder placed on canvas shelves.

On the Continent, the powder is chiefly granulated in drum-sieves, generally made of perforated parchment skins or of copper, fitting into each other, and fixed in a frame to which rotary motion is communicated by proper machinery. On the uppermost of these is placed a circular piece of heavy wood, as *lignumvite*, sometimes loaded with lead, which traversing the surface of the sieve, gradually reduces the fragments of the powder, until they are sufficiently fine to pass through the perforations or meshes.

PROPERTIES.—Good powder, according to ABEL and BLOXAM, should be perfectly uniform in texture; light specks or glittering points indicate an incomplete mixture. The grains should be sufficiently hard not to be easily crushed between the fingers, and not to soil these or a piece of paper by mere contact. Gunpowder should burn rapidly, leaving only a *very slight* residuum. If inflamed upon white paper, it should blacken it but slightly, and should on no account set fire to it. Powder is inflamed by any burning substance, by an electric spark, by red-hot metal, or by violent concussion. It does not ignite, however, by exposure to a temperature below redness. If subjected in an atmosphere of hydrogen or carbonic acid to a gradual increase of temperature, the sulphur may be completely separated, subliming upon the cool portion of the vessel.

It has been proved that powder may be inflamed, not only by the concussion of hard bodies, but by that of comparatively soft ones, provided it be sufficiently powerful. Experiment has shown that powder placed upon lead, or even upon wood, may be ignited by the shock of a leaden bullet fired at it.

No doubt the inflammability of a powder is greatly influenced by its physical state. A fine-grain powder will burn much more rapidly than powder of a larger grain. The greater the density, the more gradual is its combustion. Angular powder will burn more speedily than the round-grained, and the inflammability of powder is not only retarded by the presence of moisture, but also by the glazing.

Powder in which the theoretical proportions are exact, and in the manufacture of which a very inflammable charcoal has been used, the ingredients having

been mixed without the application of very great pressure, will undergo, when ignited, an almost instantaneous decomposition. Such a composition, in many respects, resembles the fulminates; the strain which it exerts upon the fire-arm is far too powerful; hence it is not so generally applicable as a more gradually disintegrating mixture.

Gunpowder always attracts more or less moisture, since charcoal, however dense, absorbs humidity from the air; though, of course, the hygroscopic property of powder is considerably increased by the use of porous charcoal in its manufacture, or by the presence of any considerable quantity of powder-dust. Powder, manufactured with perfectly pure nitrate of potassa, is found, if preserved in dry stores, to absorb about 0.5 per cent. of moisture; the amount naturally increases considerably if it is kept in a damp situation. Fine-grain powder is generally found to absorb moisture more rapidly than the large-grained.

The amount of ash left upon the ignition of gunpowder varies according to the purity of its ingredients, the proportions employed, and, more particularly, the nature of the charcoal used. Its gradual accumulation in a fire-arm is a source of great inconvenience, since it soon renders it foul and difficult to charge, thus limiting the number of rounds that can be fired in rapid succession, without cleaning out the instrument. This *fouling*, as it is termed, is avoided to some extent by the use of a small quantity of some fatty substance, which lubricates the barrel, and, by preventing the adhesion of the ash, promotes its expulsion by the gases as they make their escape.—*Abel and Bloxam*.

BISHOP affirms that gunpowder explodes exactly at the temperature of 600°. When exposed to a heat of 500°, its nature becomes totally changed; not only is the whole of the moisture expelled, but the saltpetre and sulphur are reduced to the fluid state. The powder on cooling is found to have changed from blackish-grey to an intense black; the grain has become extremely indurated, and by exposure even to very moist air, it then suffers no alteration by imbibing moisture.

The specific gravity of gunpowder, according to Dr. URE, as taken by him with five different kinds in oil of turpentine, varied from 1.793 to 1.80.

ANALYSIS.—The following is the ordinary method of analysing gunpowder:—

The water is first estimated by submitting a small portion, say three or four grammes of the sample to be examined, to a temperature of 212°, in a water-bath, until it ceases to lose weight. Some chemists prefer placing a known quantity over sulphuric acid *in vacuo*, but this method takes much more time, and the former is sufficiently accurate for all ordinary purposes. The loss after drying shows the amount of moisture in the sample, from which the per-centage may be readily calculated.

It may be well for the Editor to remark here, that the quantity of water should be a *mere trace*, if any. If it is found to contain several per cent. of water, it may be rendered again perfectly good by careful exsiccation.

The next step is the determination of the nitrate of potassa, which is effected by boiling the powder in

which the humidity has been determined, in about six times its weight of water; the residuum is then carefully collected on a tared filter, washed with tepid water until a few drops of the filtrate when evaporated upon platinum foil give no residue; the insoluble matter upon the filter being then desiccated at 212° , and weighed, the loss will indicate the amount of nitrate of potassa. The saltpetre may also be determined by evaporating to dryness the filtrate obtained as above, fusing the residuum at a low temperature, and then ascertaining its weight. Both these methods may be employed, the one thus furnishing a check upon the other.

Should the saltpetre contain chloride of sodium, as it ordinarily does, the amount of it may be determined as follows:—The dry and weighed residuum, procured as just described, is redissolved in water, and a little nitric acid and a weak solution of nitrate of silver added, when, if chlorides are present, a curdy precipitate of chloride of silver occurs; this is collected on a filter, edulcorated, dried, fused with great care in a porcelain crucible, and weighed. One gramme of the chloride of silver represents $\cdot 407$ chloride of sodium, or $\cdot 247$ of chlorine.

The amount of sulphur and carbon, respectively, may be ascertained by various methods.

One of these, devised by GAY-LUSSAC, consists in igniting in a platinum crucible a known quantity—say one gramme—of the gunpowder, with the same weight of carbonate of potassa and of nitrate of potassa, and four times the quantity of common salt; by this means the sulphur is oxidised into sulphuric acid, and may be determined as under:—The fused mass, which should be perfectly white, is dissolved in water, and acidified by means of hydrochloric acid. The solution is next filtered, and chloride of barium added so long as a deposit is occasioned. After some time, when the precipitate has subsided, the whole is filtered, and the sulphate of baryta aspersed with hot water, until sulphuric acid causes no turbidness in a portion of the washings. The precipitate is next dried, and then, as much of it as is possible being detached from the filter paper, the latter is burned in a platinum crucible until the whole of its carbonaceous matter is destroyed; the former introduced, heated to redness, and weighed. Each $116\cdot5$ parts of sulphate of baryta represent forty-nine parts of monohydrated sulphuric acid, and consequently sixteen of sulphur.

The per centage of moisture, nitrate of potassa, and sulphur being calculated, the difference indicates the amount of carbon.

WHITE GUNPOWDER.—AUGENDRE has described a new kind of gunpowder, consisting of one part of ferrocyanide of potassium, one part of white sugar, and two parts of chlorate of potassa. These are reduced to powder separately, and are then mixed with the hand. In experiments with small quantities, they may be pounded together in an agate mortar. Not the least fear need be entertained of the effects of the most powerful friction. In preparing it on a larger scale, the mixture is moistened with two or three per cent. of water, and triturated in a bronze mortar with a wooden pestle; fifteen minutes' pounding suffices for

small quantities, as the ingredients do not require such intimate admixture as in the preparation of ordinary gunpowder. The powder is granulated in the usual way, and dried in the air.

Gunpowder thus prepared is white; fires with the greatest ease, both in the granular state, and in that of an impalpable powder, by contact with an incandescent body; the flame with which it burns is greater than that of ordinary powder, and it leaves less residue. As taken from the mortar, it is perfectly inflammable, so that there never need be any apprehension of its missing fire. It must be exceedingly dry for a violent blow of iron to explode it; friction between two polished bodies never produces this effect, nor does striking wood upon wood, or wood upon metal. It is formed of substances, the composition of which is well determined and fixed, and it can, therefore, always be obtained of the same strength. The materials are unalterable by the action of dry or humid air, so that they can be kept for any length of time, which cannot be done with the charcoal used for the ordinary article. The manufacture requiring less time, a fortress might, in case of necessity, be provided with the several constituents in powder, and the mixture made when required, by which means the danger attendant upon large deposits of gunpowder would be avoided. The force is much greater, so that there is space for a larger number of charges in the artillery caissons. The dust having the same effect as the grain, each constituent might separately be reduced to a very fine powder, and the whole commingled in a leather barrel.

But though possessed of all these superiorities over common gunpowder, it is not free from serious disadvantages, one of which is, that it oxidises iron barrels very much, and its use is consequently limited to bronze ones, and to the filling of hollow projectiles. It is more easily inflamed than common gunpowder, but not so readily as the other compounds of chlorate of potassa which have been prepared for the same purposes.

AUGENDRE directs attention to the circumstance, readily conceivable from the behavior of chlorate of potassa towards several other substances, that the greatest care should be taken to avoid introducing into the mixture any charcoal or sulphur, or mixing with it any ordinary gunpowder.

The proving of gunpowder, and many other subjects connected with the present article, are not of a sufficiently chemical nature to be treated of here.

STATISTICS.—Gunpowder is always packed in strong oak barrels, containing from eight to one hundred pounds each, the latter being the maximum weight allowed by Government to be contained in a single package. When for sporting purposes, it is in canisters and strong papers.

Owing to gunpowder being entirely free from duty, the returns of the Board of Trade can scarcely be expected to give even an approximation to the amount of imports and exports. Indeed, the import returns during the years 1850 to 1853 inclusive are entirely blank, while, for 1854, they are registered as one hundredweight, and in 1855, 11,851 hundredweights. During the years 1850-55 inclusive, there were no returns of exports.

GUTTA-PERCHA.—This valuable substance, the name of which is the same in all languages, and which was unknown in Europe previous to the year 1843, is the inspissated juice of a tree which grows in the Malayan forests and the islands of the Eastern Archipelago. In its origin, character, and composition, it is analogous to caoutchouc, but wants the peculiar elasticity of that substance; on the other hand, it possesses special and distinct properties, which render it applicable to an extraordinary variety of important uses, and which, within the short time that has elapsed since its introduction into Europe, have given a remarkable development to its manufacture.

It may not be out of place, even in a scientific work, to correct an erroneous mode of pronouncing the name of this substance, which has become very general. The name is a pure Malayan one, and not Latin, as might be supposed from a mere coincidence in the spelling—*gutta* meaning in the Malay language the gum or concrete juice of a plant, and *percha* the particular tree from which the juice is procured. Dr. MONTGOMERIE, its discoverer, states that the *ch* is not pronounced hard like a *k*, but like the *ch* in the English name of the fish *perch*; and that if a European were to inquire of a Malay for *gutta perka*, he would be told the thing was unknown, when perhaps plenty of the *gutta-percha* might be procurable by pronouncing the name properly. He adds, that had he thought there was a probability of the name being mispronounced, he might have used the uncouth orthography *perisha*, but then it would have run the risk of being taken for a Russian or Polish appellation.

HISTORICAL NOTICE.—It appears that this substance, though only of recent introduction into commerce, was brought into England in the days of TRADES-CANT, as a curious product, under the name of *mazer wood*; and subsequently it was frequently brought from China and other parts of the East, under the designation of india-rubber, in the form of elastic sticks, whips, and other trifling articles. The products of the East Indies, shown by the Honourable East India Company at the Great Exhibition, proved that the natives of the country in which the *gutta-percha* tree grows, knew also how to appropriate it to the manufacture of different kinds of vases, and that European industry and the wants of an advanced civilization have only developed its application to a greater variety of uses than were known or required in the countries to which it belongs.

The merit of first appreciating its value and making it known in Europe, is claimed by two individuals, who seem to have endeavored about the same time, and quite independently of each other, to bring it into public notice, namely, Dr. WILLIAM MONTGOMERIE, a Scotchman, for some years assistant-surgeon to the Residency at Singapore, on the Malay peninsula; and Sir JOSE D'ALMEIDA, who had been for many years resident in the same settlement. This last-named gentleman came over to England in the beginning of the year 1843, bringing several samples of the *gutta-percha* with him; and, among other channels of communication with the scientific world, had the honor of presenting specimens to the Royal Asiatic Society,

for which he received their letter of acknowledgment and thanks. On the whole, however, the merit of priority of discovery seems, by general assent, to be assigned to Dr. MONTGOMERIE, who, in point of fact, was not only the first European who discovered the value of the product, but the first who exerted himself actively and successfully to bring it into general use. Before the attention of this gentleman was directed to it, it was not only quite unknown to Europeans in general, but was known as an article of value only to a few of the inhabitants even of those localities in which it is produced, and was applied by the natives to very trifling uses; being chiefly employed to make handles for *parangs* or wood-choppers, as a substitute for wood or buffalo-horn.

The valuable qualities of the substance were no sooner publicly announced than it came into general demand. The immediate effect of its discovery may be compared to that of the gold-fields in California and Australia; and perhaps no substance except the precious metals has been more eagerly sought after or more highly appreciated. Its singular adaptation for an infinite variety of purposes was quickly recognized, and an extensive trade in it sprang up almost immediately. In the year 1844, previous to which its very name was unknown to European commerce, two hundredweight of it were shipped experimentally from Singapore. In 1845 the exportation of it from that port rose to one hundred and sixty-nine piculs—a picul being equivalent to 133.3 pounds; in 1846, to five thousand three hundred and sixty-four piculs; in 1847, to nine thousand two hundred and ninety-six; in 1848, to twelve thousand. In the first four and a half years of the trade, twenty-one thousand five hundred and ninety-eight piculs of *gutta-percha*, valued at two hundred and seventy-four thousand one hundred and ninety dollars, were shipped at Singapore; the whole of which was sent to England, with the exception of fifteen piculs to Mauritius, four hundred and seventy to the Continent of Europe, and nine hundred and twenty-two to the United States.

The knowledge of the article, stirring the avidity of gatherers, gradually spread from Singapore, Northward, as far as Penang; Southward, along the East coast of Sumatra to Java; Eastward, to Borneo, where it was found not only at Sarawak, but also at Bruné and Pontianak on the West coast, and at Reti and Passir on the East.

This eager demand for the precious gum, animated by the thirst for immediate gain, was productive of a reckless destruction of the valuable trees that produced it. Instead of simply tapping the trees to obtain the juice, as is practised in the case of caoutchouc, the monarchs of the forest were felled to the ground; a magnificent tree of fifty or one hundred years' growth was cut down, the bark stripped off, and the milky juice collected and poured into a trough formed by the hollow stem of the plantain leaf; and some idea may be formed of the havoc thus made to procure the large supplies which were imported into Singapore, when it is stated, that on an average not more than twenty or thirty pounds were procured from one tree. The result was, that in the course of three and a half years,

two hundred and seventy thousand trees were felled, in order to get at the gum. It was, therefore, apprehended that the tree, although at first sufficiently plentiful, would soon become difficult to be procured; and this would undoubtedly have been the case, had not the Gutta Percha Company, subsequently formed in England, acted with a wise precaution, and embarked a considerable capital in seeking to promote the tapping, instead of the felling of the trees.

THE GUTTA-PERCHA TREE.—For some years after the introduction of gutta-percha, the character of the tree which produces it remained a mystery. At length from specimens which were sent home by Dr. OXLEY, in 1847, Sir W. J. HOOKER was enabled to refer the plant to Dr. WRIGHT's new genus of *sapotaceæ*, called by him *isonandra*; and accordingly he proposed to designate the gutta-percha plant *isonandra gutta*—the name by which it is now known. The tree is from forty to seventy feet high, and from two to four or even six feet in diameter. It is found all up the Malayan peninsula, as far as Penang, and its favorite localities are the alluvial tracts on the foot of hills, where it forms the principal portion of the jungle. In its general aspect, says Dr. OXLEY, it resembles the Durian—*Durio Zibethinus*, Linnæus—so much so as to strike the most superficial observer. The trunk is straight; the leaves alternate; their upper surface of a pale green, and their under covered with a close, short, reddish-brown hair. The flowers are axillary, from one to three in the axils, supported on short curved pedicels,

Fig. 249.



and numerous along the extremities of the branches. The wood is described by HOOKER as peculiarly soft, fibrous, and spongy, pale-colored, and traversed by longitudinal receptacles of reservoirs filled with the gum, forming ebony-black lines. Fig. 249 is a portion of a branch of the gutta-percha tree, exhibiting also the leaves, flowers, and fruit.

There is no doubt that these are the characteristics of the tree from which the substance known as gutta-percha is obtained; but SEEMAN states that the gum termed by the Malays gutta-percha, is not the produce of the *isonandra gutta*, but that of a botanically-unknown tree, a species of *ficus*, and that the substance which has been improperly termed gutta-percha by Dr. MONTGOMERIE, and must now continue to be so called, is really the *gutta-taban*. It must ever be an object of regret, he remarks, that on the first introduction of the *taban gum*, its real name was not promulgated. The name, however, is now fixed beyond recall; and, to prevent misunderstanding, the reader has only to bear in mind that the substance known in Europe as gutta-percha, though stated by SEEMAN to be the *gutta-taban* of the Malays, is really the produce of *isonandra gutta* above-described.

EXTRACTION AND INSPISSATION OF THE GUM.—The sap or gutta circulates between the bark and body, in vessels, of which the course is well marked by black longitudinal lines upon the wood. To obtain the juice, it was formerly the practice, as already stated, to cut down the full-grown tree close to the root; rings were then made in the bark at distances of about twelve to eighteen inches apart, and a cocoa-nut shell, spathe of a palm, or such like receptacle, was placed under the fallen trunk, to receive the milky sap that immediately exuded upon every fresh incision. The quantity of gutta obtained from each tree so destroyed varied from five to twenty catties; so that taking the average of ten catties, it would require the destruction of ten trees to produce one picul, or one hundred and thirty-five pounds of gutta.

Fortunately, experience has now taught the natives that the milky juice may be collected by cutting notches here and there in the trunk of the living tree, and that in this way it may be preserved for future tapplings. This more economical method is rapidly gaining ground; and, considering the vast extent of territory occupied by the tree in its several varieties, and that European industry is now so deeply interested in its culture and preservation, there is little danger of the supply becoming exhausted.

The sap coagulates in a few minutes after it is collected; but before the crude gum becomes quite hard, it is kneaded by hand into compact oblong masses, from seven to twelve inches in length, by four or five in thickness. This part of the work is mostly performed by women, as represented in the annexed engraving—Fig. 250—which exhibits not only the ordinary appearance of the native Malays, but the character of the internal forest scenery of the tropical regions which they inhabit.

Dr. OXLEY's account differs somewhat from the preceding. He states that the sap, instead of coagulating and being made up into blocks on the spot, is collected in bamboos, taken by the natives to their houses, and boiled, in order to drive off the watery particles and inspissate it to the consistence it finally assumes. He adds, however, that although the process of boiling appears necessary when the gutta is collected in large quantities; yet, if a tree be freshly wounded, a small quantity allowed to exude, and it be collected and

moulded in the hand, it will consolidate perfectly in a few minutes, and have all the appearance of the prepared article. The apparent discrepancy between the

Fig. 250.



two statements may perhaps be explained by the fact, that Dr. OXLEY's account was written when the trees were uniformly felled to procure the juice, and when the latter was, therefore, collected in considerable quantities at a time, which rendered boiling necessary; whereas, when slowly collected in smaller portions from a number of living trees, the watery ingredient will evaporate as the juice exudes, and, with the assistance of kneading or moulding by the hand, that consolidation will take place to which Dr. OXLEY alludes as occurring in the case of small quantities.

PROPERTIES.—Gutta-percha, when quite pure, is of a greyish-white, but, as brought to market, it is more ordinarily found of a reddish-brown hue, arising from chips of bark that fall into the sap in the act of making the incisions, and which tinge it. It may be readily obtained in a pure state by dissolving the crude gutta in sulphide of carbon, filtering the turbid and brown solution under a bell-glass, and evaporating the filtrate by simple exposure to the air in a flat porcelain dish. After desiccation, the thin plate or cake of purified gutta is easily detached from the vessel by covering it for a few minutes with cold water, which destroys the adhesion. Nearly the whole of the extraneous tinctorial matter remains on the filter, with a portion of the undissolved substance.

Thus fabricated, the gutta is almost white, is semi-transparent in thin leaves, but opaque in thicker plates; it is greasy to the touch, and has a peculiar leathery

smell, somewhat similar to that of india-rubber. Its specific gravity, as determined by Dr. A. ADRIANI, was 0.999 at 68°, when subjected to the action of an air-pump to remove the adhering water-bubbles; without this precaution, it was only 0.728. A specimen of gutta-percha mechanically purified, and shaped in cakes, was found to have a specific gravity of 0.966°. The average density of the commercial article is 0.975°. The great variations in its density under different treatment imply a peculiar porosity in its structure, which was experimentally verified by PAYEN. Having placed a drop of its solution in bisulphide of carbon on a slip of glass, and allowed it to evaporate in the manner above-described, so as to obtain a thin film of the substance in a state of purity, he observed with the microscope numerous small holes or cavities, which were rendered still more visible by a drop of water; the liquid gradually insinuating itself, and rendering the film more opaque, while the cavities were observed, by means of the lens, to be enlarged. Similar results were obtained by keeping immersed in water for a considerable time, thin transparent laminae, obtained by the evaporation by heat of a solution of gutta-percha.

It was these observations which led this eminent chemist to conclude that the common commercial gutta-percha, retaining, in consequence of its porosity, a great many minute particles of air, owed to this circumstance its appearance of possessing a less density than that of water. In fact, on stretching gutta-percha under strong pressure, and immediately cutting the strips thus produced into very small pieces under water, the greater part of the fragments fell to the bottom of the vessel—some immediately, others absorbing a certain quantity of moisture. The same result was also obtained by keeping very thin leaves of gutta-percha, prepared by different methods, immersed in water deprived of air; their pores being gradually filled with the liquid, they became heavier than it, and then ceased to float. Gutta-percha is also heavier in proportion to the length of time it has been exposed to the air, particularly in thin leaves.

The porosity of gutta-percha, which allows a slow transudation of liquids through its mass, is the principal drawback to its use when formed into bottles or other vessels for holding chemical fluids. This porous structure becomes changed into a fibrous texture when it is drawn out so as to double its length; then, retaining little extensibility, it supports, without breaking, the action of a force equal to double that required for its elongation in the first instance.

Gutta-percha is a bad conductor of both electricity and heat. When rubbed it becomes negatively electric, and if dry, is an insulator equal in efficiency to shell-lac. Hence, among many other important applications, which will be noticed afterwards, its extensive employment in the covering of wires for the submarine telegraph.

But the great peculiarity of this substance, and that which makes it so eminently useful for many purposes, is the effect of heat upon it, applied either directly, or through the medium of boiling water. At ordinary temperatures it is a tough inelastic substance, and cold water has no effect upon it; from 32° to 77° it possesses about as much tenacity as thick leather, with rather

less flexibility; towards 120° it softens, and becomes sensibly doughy, although still very tough; and when raised above 150°, either by exposing it to the fire or by immersing it in hot water, it becomes soft and plastic, so as to be capable of being moulded to any required shape or form, which it retains upon cooling. Its ductility is such that, at a temperature of from 150° to 240°, it is readily extended into thin sheets, or drawn into threads or tubes; its flexibility and ductility diminish as the temperature becomes lower. It does not possess, at any temperature, the peculiar elastic extensibility which characterizes caoutchouc. When cold, it again becomes hard, and possessed of extraordinary tenacity.

It melts at 248°, and may be made to boil without acquiring a sensible color; the transparent fluid gives abundant vapors, which are condensable into a nearly colorless oily liquid. The portions last distilled have a brownish-orange hue, and a thin layer of carbonaceous deposit remains adherent to the sides of the vessel. Heated beyond this point, it is decomposed, yielding inflammable products; a strip of it cut off burns with a bright flame, emitting sparks, and dropping a black residuum in the manner of sealing-wax, which in its combustion it very much resembles.

Common gutta-percha is perfectly insoluble in water at any temperature; it effectually resists damp, and hence its valuable applications as a waterproofing material, and as a substitute for leather in soling boots and shoes. It likewise withstands the various influences which excite fermentation, but experiences a sort of doughy fusion when exposed to the direct action of the solar rays in summer. Soda and potassa, even when caustic and concentrated, ammonia, saline solutions of all kinds, water containing carbonic acid, the various vegetal and mineral acids, do not act upon it. It is not affected by fermented liquors, such as wines, beer, *et cetera*; even alcohol scarcely dissolves a trace of it. Olive-oil has no action upon it when cold, but when hot, it dissolves a small portion of it, which is again precipitated on cooling.

Concentrated nitric acid attacks gutta-percha rapidly with effervescence, and an abundant evolution of fumes of nitrous acid; the gutta is disintegrated, and colored of a brownish-orange red; it becomes doughy, and afterwards solidifies by degrees, but remains friable. Concentrated sulphuric acid produces the same effect more gradually, rendering it brown, and causing its disintegration, with a sensible evolution of sulphurous acid. MILLER affirms that hydrochloric and dilute hydrofluoric acids have no action upon it; hence it is employed in the preparation of bottles and vessels used for containing these liquids; but PAYEN states that hydrochloric acid, in its saturated solution in water at a temperature of 68°, attacks gutta-percha slowly, and gives it a more or less deep-brown color, at length rendering it brittle.

The same chemist remarks that, in the cold, and even by heat, not more than 0.15 to 0.22 of the gutta-percha is dissolved by anhydrous alcohol or ether; but ARPPE states that thirteen per cent. of gutta-percha is dissolved by alcohol, and that, separated from mechanical admixtures, it is soluble in ether which is free from alcohol,

whereas, if it has been previously treated with alcohol, it does not dissolve in ether. This observation, which seems to have been overlooked by M. PAYEN and other chemists, has an important bearing on the analysis of gutta-percha.

Benzol and oil of turpentine dissolve gutta-percha partially when cold, but almost completely by heat. One part of the gutta requires for its solution from four to six parts of oil of turpentine. Bisulphide of carbon and chloroform dissolve it cold, and by either of these solvents it may be obtained pure in the manner already described.

ELEMENTARY COMPOSITION.—Gutta-percha is, like caoutchouc, a carbide of hydrogen, and nearly isomeric with that substance, as the following analyses will show:—

	Gutta-percha.		Caoutchouc.
Carbon,.....	86.36	....	87.2
Hydrogen,.....	12.15	....	12.8
Oxygen,.....	1.49	....	—
	100.00		100.0

It is a question indeed whether the elementary composition of the two substances is not precisely the same, the small quantity of oxygen detected by Dr. MACLAGAN in gutta-percha being probably derived from the air during the process of purification. Its acknowledged porosity, and the difference in its specific gravity under different conditions, are facts which afford a strong presumption in favor of this view.

But like other isomeric substances, gutta-percha and caoutchouc, though strikingly similar in many of their properties, and more especially in their resistance to the action of most chemical agents, differ considerably in other respects, and this must be attributed to the different grouping of their elementary constituents, if not to the actual presence of oxygen as one of the essential ingredients of gutta-percha.

Professor PAGE states that gutta-percha, when rolled into thin sheets or drawn into ropes, comports itself like a fibrous substance, which is not the case with caoutchouc. A strip cut from a thin sheet of gutta-percha may be stretched considerably in one direction, that is, in a line with the fibre, but any attempt to stretch it across this is followed at once by a rupture. It is not so with a sheet of caoutchouc, which will stretch *equally well in all directions*. On examination of sheets of these two substances—so far believed to be *isomeric*—a marked difference of texture is at once perceived. The caoutchouc gives little or no change of color, while the gutta-percha exhibits a beautiful spectacle. It appears to be built up of prisms of every variety of hue, and, as it were, fused into each other. Professor PAGE states that it resembles more nearly some specimens of ice which he had examined, than anything else. The caoutchouc and gutta-percha must be kept under considerable tension during the examination.

PROXIMATE PRINCIPLES.—PAYEN states that purified gutta-percha is formed of three proximate principles, very different from each other as regards their properties, but isomeric as regards their elementary composition, and also isomeric with purified caoutchouc, being all of them carbides of hydrogen, and

which represented by the formula $C_8 H_8$. These three proximate principles, which he terms *gutta*, *albana*, and *fluavile*, he describes as being found in gutta-percha in the following variable proportions:—

	Centesimally.
Gutta,	78 to 82
Albana,	16 to 14
Fluavile,	6 to 4
	100 100

PAYEN commenced his experiments by submitting the gutta-percha to the action of alcohol. Reduced to thin leaves, it was treated, in a close vessel, with fifteen to twenty volumes of cold-anhydrous alcohol; the heat was raised slowly, by means of the water-bath, to the point of ebullition, 172° , and kept at this temperature during several hours; the liquid was then filtered whilst boiling, and left in a closed flask, when it was found, at the end of from twelve to thirty-six hours, to begin to deposit on the sides of the vessel, and on the surface of the solution, white opaline granules, distant from one another, but some of them in groups; their size gradually increasing for some days. These granules, carefully examined under the microscope, were found to have the form of spherules truncated by the sides of the vessel. Their surface was either smooth or bristling with very small, transparent, elongated, lamellated crystals. Some superficial fissures appeared to indicate that these spherules were formed of a sort of transparent yellow nucleus, covered with a white pellicle; and PAYEN ascertained on examination that such was really their singular crystalline structure, of which perhaps no other example is known. He found also that cold anhydrous alcohol dissolved the whole of the yellow internal spheroidal substance, while the superficial pellicles, in the interior of which the alcohol had then substituted itself for the solid yellow globules, appeared consequently whiter and more transparent. The alcoholic solution, which had been for some days depositing this complex spheroidal crystallization, was again capable of taking by heat a further portion of the two proximate principles remaining in the substance, allowing a fresh quantity to crystallize on cooling, and thus to be developed respectively in the white pellicle and yellow nucleus. The extraction was completed by returning the boiling alcohol several times upon the gutta-percha till nothing more was dissolved.

The solid substance, which entirely resisted the action of the alcohol, possessed, with some modifications, the principal properties of crude gutta-percha; and this is what PAYEN termed *pure gutta*, or simply *gutta*. Of the two other organic principles developed by the method which he adopted, the *white crystalline resin* which covered the spherules was what he called *albana*; and the *yellow resin*, which was much more soluble in cold alcohol than the other, was the substance which he termed *fluavile*. The commercial varieties which he examined gave him the proportions above stated; their special properties were as follows.

1. *Pure Gutta*.—It will be seen that the most abundant of the three principles distinguished by PAYEN is the so-called *pure gutta*, or that portion insoluble in

alcohol, and which is described by the same chemist as being insoluble in ether. M. PAYEN probably failed to effect its solution, from the circumstance that he employed the same gutta which had previously been treated with alcohol; in that case, according to M. AEPPE, it is not dissolved by ether.

PAYEN describes his *pure gutta* as presenting the principal properties of the commercial substance. It is white, transparent at a temperature of 212° , when all its parts are melted together; opaque or semi-transparent when cold, from its then acquiring a structure which causes the interposition of air, or of a liquid possessing a different refraction from its own. He states that this structure appears still more distinct than in the natural substance containing all these principles. In thin sheets, and at a temperature of 50° to 86° , it is supple, tough, extensible, but not very elastic. At 112° it softens and turns back upon itself, and becomes more and more adhesive and translucent in proportion to the elevation of temperature, undergoing a sort of doughy fusion, which becomes more distinct towards 212° to 230° . Heated beyond this point, it melts, boils, and distils, furnishing a pyrogenous oil, and eliminates carbides of hydrogen. Its behavior with acids, alcohol, and oils, chloroform and bisulphide of carbon, is the same as the commercial article.

After the extraction, by means of ether, of the two resins contained in the thin leaves of white or purified gutta-percha, leaving the last portion of ether with which they were impregnated to evaporate in the open air, these leaves, inclosed in a flask, experienced, after remaining there for two months at a temperature of from 68° to 82° , an alteration which appeared to depend on their porosity, the action of the air, and perhaps the ether retained in their pores. However it be, these leaves had then acquired new properties; they were brittle; exhaled a very distinct sharp odor; brought into contact with an excess of anhydrous ether, they were partially dissolved; the soluble portion obtained by the evaporation of the ether, and exsiccation at 194° , was glutinous and translucent; it became opaque and hard by cooling down to 14° .

The same chemist states as a fact which he had personally ascertained, that thin leaves, exposed for eight consecutive days to the action of the sun in moist air, were discolored, and that their substance had become in great part soluble in ether.

2. *Albana*.—The albana, or crystalline white resin, presents itself as a light pulverulent mass, apparently opaque, which, under the microscope, exhibits thin transparent lamellar crystals. From 32° to 212° it does not experience any sensible change; its fusion commences at 320° ; at 347° to 356° it acquires an oleiform fluidity and complete transparency, without any noticeable color; it solidifies on cooling, shrinks, which causes it to split, and remains transparent and a little heavier than water.

The crystalline resin is not attacked or readily oxidized by either cold or boiling water; or by hot or cold caustic alkaline solutions, ammonia, and the various dilute acids. Monohydrated sulphuric and nitric acids attack it rapidly, producing similar phenomena to those observed in their action upon pure gutta.

Hydrochloric acid, on the contrary, does not act upon the white resin.

3. *Fluavile or yellow resin.*—This amorphous transparent resin, of a lemon or orange color, according to its thickness, is a little heavier than water, solid, and even hard and brittle at 32°; it gradually becomes more flexible in proportion as the temperature is raised; at 122° it becomes pasty; it does not become completely fluid below 212° to 230°. Heated beyond this point it boils, but then gradually undergoes considerable alteration, becomes brown, and evolves acid fumes and carbides of hydrogen. It strongly retains the alcohol in which it has been dissolved; but is separated from it by heating *in vacuo* to 212°, until bubbling entirely ceases.

This resin is soluble in the cold in alcohol, ether, benzol, turpentine, bisulphide of carbon, and chloroform: all these liquids, when evaporated, leave as residue the amorphous resin. Dilute acids, concentrated alkaline solutions, and ammonia, do not attack the yellow resin. Monohydrated sulphuric and nitric acids act upon it rapidly, producing phenomena analogous to those exhibited with the other two principles. Hydrochloric acid, even in its saturated solution at 68°, is without action upon it. But the most remarkable character of this resin is the power of forming, under the circumstances already indicated, those globose crystals covered with a white pellicle of another resin, and presenting in their complex form the appearance of opaline spherules.

MANUFACTURING PROCESSES.—It has been stated that the gutta-percha, after its extraction from the tree in the form of a milky juice, is first allowed to coagulate, and then made up into lumps or blocks of some pounds' weight. These, as they arrive in Europe, are far from being pure, for besides containing chips of bark, leaves, and other adventitious substances which fall accidentally among the juice, the natives make no scruple of introducing stones, earth, and other rubbish, to increase the weight of the blocks. The first and most essential process in the manufacture of gutta percha is, therefore, its purification; and in fact, ever since its introduction into Europe, gutta-percha has found everything provided for the purpose of cleansing it, being worked by processes and instruments very similar to those which had been previously employed in the purification of india-rubber. It is also vulcanized, and cut or moulded into different shapes, in much the same manner. The general nature of the operations may be briefly described as follows:—The blocks of gutta-percha being first cut into slices by revolving knives, are softened by means of hot water, and then divided and torn into shreds by the same machine that is used for india-rubber, which serves also to knead the gutta-percha in such a manner that the crushed stones and earth may be separated from it on being diluted in the water; it is then dried, and submitted, by means of a powerful machine, to a mastication similar to that which caoutchouc is made to undergo; and when, after some hours of kneading, the mass has become homogeneous and sufficiently softened, it is extended by the drawing-mill into cylindrical cords, moulded into tubes of various diameters, or spread out by means of the flattening machine into sheets of dif-

ferent thicknesses, which are finally divided into bands or slivers, and from these are cut out with a stripping tool the pieces which are required to be employed in different uses.

These various operations, together with the vulcanization of gutta-percha, will now be described successively and in detail—premising that in this country the manufacture is confined to two or three companies, which work the various patents secured from time to time by Mr. HANCOCK and others. A simple description of the manufacture, as conducted by the London Gutta-Percha Company, will, therefore, embrace all that is really important in the different operations.

PURIFICATION.—The Cutting Machine.—When a visitor enters the works of the Gutta-Percha Company, he observes in the yard or court the imported blocks of the raw material piled in great heaps. These blocks, when they are required for use, are first taken from the heaps to the cutting or slicing machine, which is a large solid vertical disc of iron, armed on one side with sharp knife-edges, and revolving at the rate of two hundred turns per minute against the extremity of a sloping iron table. The block of gutta-percha being brought to the edge of the table, is rapidly caught by the knives, and literally reduced to shavings, which fall into a receptacle beneath.

Fig. 251 is a side elevation of this machine, and Fig. 252 a front elevation of the disc, with part of the frame. The revolving disc, *B*, is a circular iron plate, of about five feet diameter, into three slots in

Fig. 251.

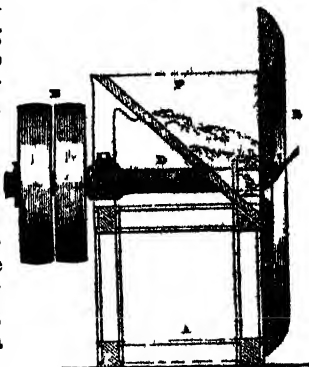
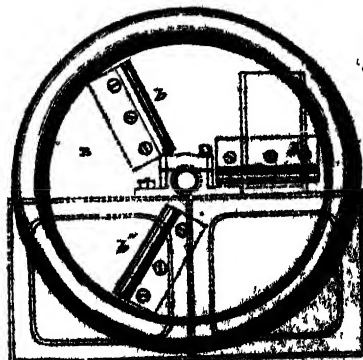


Fig. 252.



which are inserted three radial knives, *b*, *b'*, *b''*, in a similar manner to the iron of an ordinary plane or spoke-shave. Supported by the frame *AF* is the shaft *D*, to one end of which the plate *B* is attached, and to the other the strap-pulleys *EE'*, by one of which motion

is communicated to the shaft from a steam-engine, or any other convenient first mover. C is an inclined shoot, down which the lumps of crude gutta are dropped against the knives of the revolving disc, and are cut into slices of a thickness corresponding to the degree of projection given to the knives.

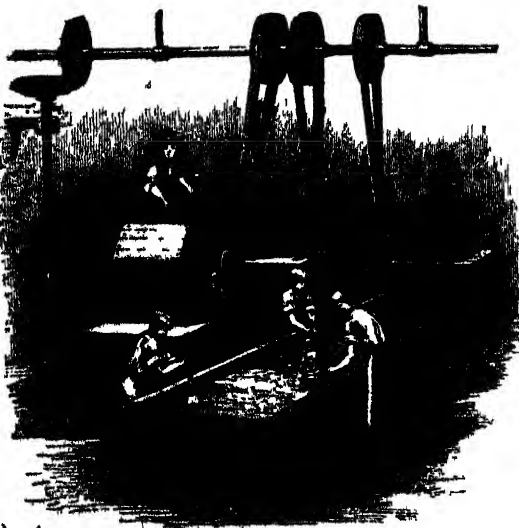
The knives are represented in Fig. 252 as being straight, but Mr. HANCOCK, the patentee, states in his

Fig. 253.



specification, that where the gutta-percha to be cut happens to be of a more than usually hard or intractable character, he finds it advantageous to substitute knives of a curved or reaping-hook form, on account of their more gradual mode of action. The machine, which is

Fig. 254.



put in motion at the Gutta-Percha Company's works through the agency of two fifty horse-power engines, is represented as in operation in Fig. 253; and it may be remarked, in passing, that the stones and other

adulterative materials which the candidity of the Malay gatherers has added to the mass, are often discovered by this process, very much to the injury of the cutters.

First Boiling and Teasing.—Having been reduced to shavings, the gutta-percha must next be perfectly cleansed of the dirt, leaves, and other extraneous matter. This is effected by throwing the shavings into a large tank containing water, as shown in Fig. 254, to which the waste steam of the engine is conveyed, for the purpose of boiling. This process softens the whole into a fluid mass, and separates the more considerable impurities, which, by the agitation of the boiling, sink to the bottom. The greater part of the rubbish having thus subsided, the partially-purified gum is collected into one mass, and carried to what is called the *teaser*—a sort of large circular box, containing a cylinder or drum covered with rows of bent jagged teeth. Two of these machines are represented in the same figure. Revolving at the rate of about eight hundred turns in a minute, the teaser quickly tears the mass into shreds, which fall into a vat of water beneath. Here the gutta-percha, being in its naturally porous state lighter than water, floats upon the surface, while the impurities disengaged from it by the action of the teaser fall to the bottom. The gutta-percha is now cleansed from all impurities; it has a crisp and fresh-looking appearance, and is ready for the next operation, which consists in working and kneading it into a homogeneous mass.

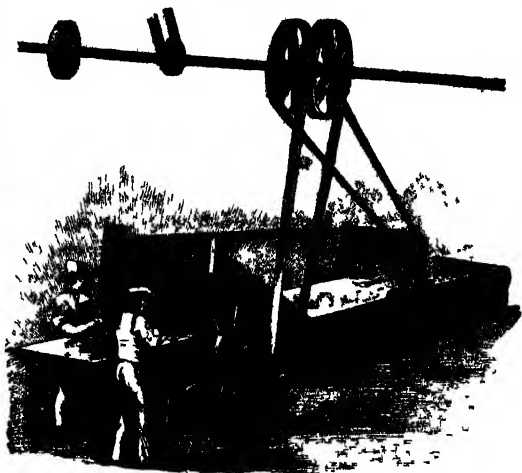
Second Boiling and Kneading.—The operation of teasing is followed by a second boiling, which has the effect of blending the fragments of the now purified substance into a warm soft mass, and in this state it is introduced into the *kneaders* or *masticators*, which are thick, strong, circular iron boxes, about three feet long and a foot and a half deep, containing revolving cylinders armed with cogs or pins on their surface. The cylinders and their containing boxes are of cast-iron, and are heated by steam. The gutta-percha, when introduced, is thus kept in a soft state, and being carried round by the action of the revolving cylinders, it is forcibly squeezed against the sides of the box; while, by the action of the cogs or pins, every air-bubble is expelled, and the whole is brought to a perfectly homogeneous mass of uniform consistency, without a particle of water in its composition.

In April, 1853, a patent was taken by Mr. NICKELS for using two rollers with screws on their surfaces, in place of teeth or projections, for masticating or kneading. The rollers work parallel, and nearly up to each other; and in each of the threads of the screw-rollers there are notches, which the patentee prefers to be made in a diagonal direction. This form of machine is considered the most effective, and is now most commonly used.

ROLLING INTO SHEETS.—In the state in which the gutta-percha comes from the kneading or masticating machine, it is ready for being manufactured into different shapes, and, with this view, it is now rolled into sheets, or pressed out into tubes. The first operation is required to prepare it for its subsequent conversion to most of the useful and ornamental purposes to which it is applied; and, with this view, the kneaded mass is

carried to the rolling machine represented in Fig. 255. This apparatus is similar to that employed in paper-mills, the gutta-percha, like the soft paper, passing on

Fig. 255.



an endless band between steel cylinders placed at the requisite distances apart, according to the thickness of the sheet required. By means of screws the cylinders can readily be adjusted to produce with equal ease the stoutest driving band, or the thinnest *gutta-percha tissue*, so successfully employed as a substitute for oiled silk, hydropathic bandages, *et cetera*. After passing between the rollers in a soft and impressible state, the sheet performs a long journey on the endless band, in the course of which it gradually cools and hardens, and finally appears at the other end a smooth, firm, flat sheet, which admits of being received and wound on a drum till the requisite length has been worked off. If, however, the sheet be too thick to cool sufficiently by merely travelling the prescribed distance, it is ventilated, as it passes along, by a series of fans like those of a winnowing machine.

DRAWING RIBANDS AND CORD.—When the material is required to be in bands or strips, it is generally cut into that form, while being rolled into sheets, by a series of knives so placed as to divide the sheet while yet plastic into any number of bands of the required width, just before quitting the rolling machine. The knives are set upright in a frame, edge foremost, at the requisite distances from each other, and, without interrupting the progress of the sheet, they slice it into bands, which, as before, are made to travel till they cool, and are then wound upon a drum.

In 1847, an ingenious machine was patented by Mr. CHARLES HANCOCK for cutting gutta-percha into narrow ribbands, and manufacturing it into thread or cord of any required shape. A front elevation of as much of this machine as is necessary to understand its construction, is given in Fig. 256, in which *x y* are two grooved rollers, made of steel or iron, and mounted in suitable framework. The grooves of each roller are semicircular, so that when the grooves of one roller are brought opposite to those of the other, they form together a series of circular holes, as shown in the

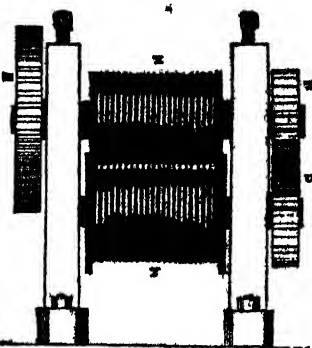
figure, at the line of contact between the two rollers. The under roller is flanged at both ends, and the two ends of the upper roller are made to fit inside of these flanges, in order to keep the cutting edges from shifting or being damaged. From the prime mover, motion is communicated to the toothed wheel, *z*, on the shaft of the roller *x*, and thence through the wheels *r* and *u*, to the roller *y*. To cut thin sheets of gutta-percha with this machine into narrow strips or ribbands, the material is passed through it cold, and only the cutting edges are brought into operation. To make round thread or cord by means of it, a sheet of gutta-percha, of a thickness equal to the diameter of the holes formed by the grooves of the rollers, is passed through it at a temperature of about 200°, by supplying the material from a feeding chamber, heated to that degree by steam or otherwise; and the threads or cords, after passing between the rollers, are received in a tank of cold water, from which they are wound on reels or drums, conveniently placed for the purpose. Or, by another method, the gutta-percha is employed in a plastic state, and passed towards the machine under a gauge, after the manner employed in the caoutchouc manufacture.

Should it be desired to produce cord of a semicircular section, the lower grooved roller is replaced by a plain roller; or should cord of a form neither circular nor semicircular, but square, triangular, hexagonal, or of any other angular form be required, two cylinders are employed, grooved in such a manner as to produce the desired shape.

Cord and thread are likewise manufactured by means of a stamp, bearing a number of close parallel sharp edges, which are brought down upon a sheet of gutta-percha so as to cut it nearly through in a series of corresponding parallel lines. The narrow slips are then severally torn off, and polished up by hand for use.

CUTTING, SHAPING, AND MOULDING.—Besides the operations above-mentioned, the gutta-percha, when formed into sheets, admits of an infinite variety of applications. Softened by boiling water or steam, it may be shaped into any required form by the hand, the knife, the mould, and the press. The numerous workshops in the establishment of the Gutta-Percha Company are crowded with men and things engaged in various operations. One apartment is occupied by the cutting and stamping room, and here the paper-cutting machine, invented by Mr. WILSON, is brought into extensive use, while moulds of every description are being employed to produce the different articles. If shoe-soles are required, the cutting machine is brought down upon a pile of stout broad bands, dividing a dozen of them at one operation into rectangular pieces, which are afterwards cut *en masse* into the required

Fig. 256.



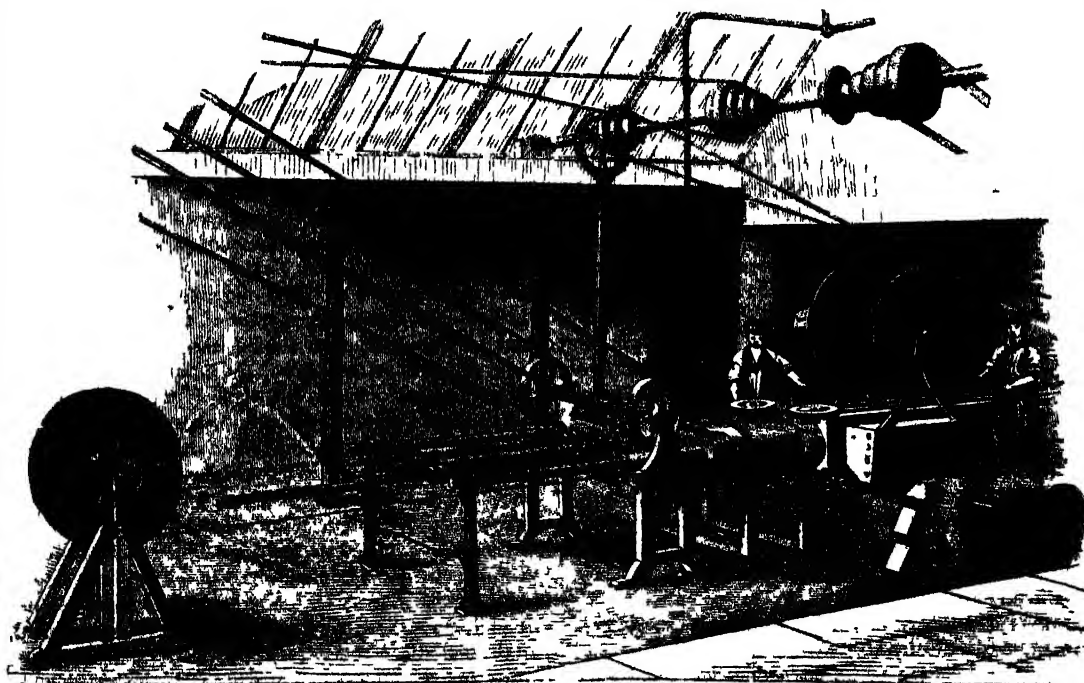
shape by means of a sharp-edged frame. In one place are seen revolving tables, bearing inverted iron moulds, from which workmen are turning out buckets, bowls, bottles, and mariners' hats, while others are moulding boxes for flax-mills, rings, whips, *et cetera*. In one apartment cisterns and trunks for emigrants are being lined; in another, ornamental mouldings, medallions, pen-trays, ink-stands, picture-frames, and other fancy articles, are stamped from electrotype copper dies or wooden moulds. For the stamping or moulding, the sheets are cut into pieces, and each piece is warmed sufficiently to take the impress of the die.

GUTTA-PERCHA TUBING.—Perhaps the most important use to which gutta-percha has been applied is that of tubing, in which form it is extensively used for pump-barrels, ship-pumps, feed-pipes for locomotive engines, siphons for mines, suction or ejection pipes for fire, garden, and washing engines; and, being unaffected by acids, it is also available in this form for bleaching with chlorine and other chemical purposes. Accordingly, while the process of sheet-rolling, already described, forms the basis of a large department of the manufacture, the making of tubes constitutes another important and distinct department—the tubes being formed directly from a softened mass of the purified material, which has passed through the kneading or masticating machine. The process, while highly inge-

nious, is exceedingly simple. The softened material is forced by a piston through a steel cylinder, terminating in a mould that consists of a solid circular piece of metal set within an iron tube, the space between the two being the thickness required. The gutta-percha thus leaves the mould in a tubular shape, but would immediately collapse unless subjected, until it cools, to an even pressure both within and without. To accomplish this, it is received from the mould into a canal of water about fifty feet in length, along which it travels, being wound off upon a drum at the other end. The water, filling the interior, and pressing equally upon the outside of the tube, preserves it in perfect shape while it speedily cools it into hardness. The feeding cylinder is so contrived as to admit of being constantly replenished with new material, so that a tube of one thousand feet has been manufactured without a single break, being the longest ever made in one piece of any substance whatever.

COATING TELEGRAPH WIRES.—Another application of gutta-percha, which may vie in importance with that of tubing, though not of such varied usefulness, is that of covering wires for telegraphic purposes. In this respect its high insulating power, combined with its flexibility and imperviousness to water, render it of essential service; and, indeed, it may be doubted whether the submarine lines of telegraph, uniting dif-

FIG 257



ferent nations, islands, and continents, could have existed at this day without the valuable assistance rendered by gutta-percha. Its introduction into Europe, contemporaneously with the inauguration of these magnificent projects, by which the earth is being girdled with wires of living intelligence, can scarcely be re-

garded otherwise than as an express dispensation of an overruling Providence to advance the progress of civilization and human happiness. A good piece of gutta-percha, says Dr. FARADAY, will insulate as well as an equal piece of shell-lac, whether it be in the form of a sheet, a rod, or filament; but being tough and

flexible when cold, as well as soft when hot, it will serve better than shell-lac in many cases where the brittleness of the latter is an inconvenience.

A thin coating of gutta-percha may be communicated to a wire by drawing it through a glass or metal tube, filled with gutta-percha in solution, or rendered fluid by heat; but for the conducting wires of the electric telegraph, whether intended to be buried in the earth, or to form the core of a submarine telegraph cable, the coating, to insure perfect insulation, must possess considerable thickness, varying from one-sixteenth to upwards of one-eighth of an inch.

Accordingly, telegraph wires are now coated in much the same manner, and by mechanism much the same in principle, as that employed for moulding tubes. This will be seen from the preceding woodcut, Fig. 257, which exhibits in actual operation the machinery employed by the Gutta-Percha Company for coating the wires of the great Atlantic cable. The central conducting wire of this cable is a *strand* made up of seven wires of the purest copper of the gauge known in the trade as No. 22; it is about the sixteenth of an inch in diameter, and is formed of one straightly-drawn wire, with six others twisted round it. This strand received a coating of three separate layers of refined gutta-percha, which together bring its diameter up to about three-eighths of an inch. The gutta-percha employed for this great work was prepared with the utmost possible care. Lumps of the crude substance were first rasped down by a revolving toothed cylinder, placed within a strong hollow case. The raspings were then passed between rollers, macerated in hot water, and well agitated. They were next washed in cold water, and then, by means of a hydraulic apparatus, driven at a boiling water temperature through wire-gauze sieves, attached to the bottom of hollow vertical cylinders. Emerging from the sieves in plastic masses of exceeding purity, the gutta-percha was then submitted to the powerful action of the masticators already described, to expel from the purified substance the last traces of water, and to render it sound, compact, and homogeneous throughout. When thoroughly masticated and kneaded, it was then introduced into the horizontal cylinders, shown in the drawing; and through these, which were heated by steam to keep the gutta-percha in a uniformly soft and plastic state, it was squeezed by means of screw pistons, worked down slowly but resistlessly by the machinery. Under this pressure the gutta-percha emerged, as in tube-moulding, through a die, which received the termination of two cylinders, and which at the same time had the strand of copper wire moving along through its centre, instead of being stationary like the mandril in tube-moulding. The strands were drawn forward between the cylinders and through the die by a revolving drum. They entered the die in the form of bright copper wire, and issued from it like brown tubes or cords of gutta-percha. Six of these strands are represented in the drawing as being coated together, ranging along side by side; and this operation was repeated a second and third time, to produce what is termed *the core* of the Atlantic cable.

PATENT MOULDING.—In March, 1855, a patent was

taken by Mr. CHARLES GOODYEAR for ingeniously extending the principle of the apparatus above-described to moulding of every description; in other words, the machine which he employs is constructed in a similar manner to those now employed for coating telegraph wires, and for moulding tubes. Like these, it consists of a cylinder or barrel, into which the gutta-percha is introduced, and into the cylinder or barrel a piston works, being operated on by a screw or rack-and-pinion, or otherwise. In this case, also, the cylinder is enveloped in a steam-jacket to keep the contained material at a suitable temperature, and in the end of the cylinder is formed a nozzle or orifice, through which the contents are forced into the mould by the motion of the piston. The moulds are constructed of two or more pieces of metal, which are held together with bolts and nuts; they are formed with a suitable interior configuration for producing the article desired; and there are two or more passages which lead into the cavity, the largest of which is for the purpose of allowing the plastic substance to pass into the mould, and the others for allowing the air contained in the mould to escape. When the piston advances, it forces the gutta-percha from the barrel or cylinder into the mould, until it begins to escape from the air orifices. The piston is then arrested, and the mould, when removed and emptied, is ready to be again filled.

VULCANIZED GUTTA-PERCHA.—Among other properties in which gutta-percha strikingly resembles caoutchouc, is the change which it undergoes when intimately mixed with sulphur or its compounds, and afterwards submitted to a somewhat elevated temperature in close vessels. By this *vulcanizing* treatment, as the process is termed, it is rendered, like caoutchouc, less readily affected by changes of temperature, and more permanently soft and elastic, so as to be better fitted for bands and other purposes. To effect this remarkable modification, it is subjected to precisely the same methods of treatment as caoutchouc, and, indeed, it is frequently combined with that substance to give it the pliancy and elasticity required for some of its applications. Accordingly, most of the patents which have been taken in connection with this subject, are not confined to gutta-percha, but embrace also caoutchouc and various combinations of these with each other, as well as with other substances.

In Vol. I., pages 448 and 449, of this work, there are two methods described of vulcanizing caoutchouc—one of which consists in kneading it with sulphur or its compounds; the other, in immersing it in liquid compounds which hold sulphur in combination, and afterwards, in both cases, exposing it to the requisite heat. Gutta-percha may likewise be vulcanized by either of these methods, or by exposing it to the action of a mixture of steam and sulphurous vapours in HARRISON'S apparatus, which was patented in 1847, and is figured and described at the pages above referred to.

In March, 1846, Mr. ALEXANDER PARKES of Birmingham obtained a patent for vulcanizing caoutchouc and gutta-percha, by dissolving it in bisulphide of carbon, coal-naphtha, turpentine, or any other suitable solvent, preferring, however, the bisulphide of carbon for the purpose, along with chloride of sulphur. The caout-

chouc or gutta-percha, when taken out of the solution, is suspended in a drying-room or stove, heated to about 80°; and, when the solvent has evaporated, the gutta-percha is well washed in water, or boiled for one hour in a solution of caustic potassa or soda, containing one pound of the alkali to a gallon of water. The gutta-percha being then dried, is ready for use.

Mr. HANCOCK, in the specification of his first patent, of November, 1846, recommended the sulphurizing of gutta-percha by means of sulphides, such as orpiment or liver of sulphur, in preference to sulphur itself; and in that specification he stated, that though a portion of sulphur might be used in place of an equal portion of sulphide, yet he considered the use of sulphur to be altogether objectionable, because of its offensive smell and tendency to efflorescence. Subsequently, however, he ascertained, as stated in the specification of his second patent, of date February, 1847, that if a very minute portion of sulphur be used along with a sulphide, a better result is obtained from a combination of the two than from either substance alone. The proportions which he found best in practice were six parts of sulphide of antimony, sulphide of calcium, or some other analogous sulphide, and one part of sulphur, to every forty-eight parts of gutta-percha. When the mixture of these materials has been effected, he places the compound in a boiler, and raises it, under pressure, to a temperature of 260° to 300°, in which state he leaves it for a period varying from half an hour to two hours, according to the thickness of the materials; by which time it becomes completely vulcanized, or, in other words, *metallo-thionized*.

In August, 1851, a patent was taken by Mr. STEPHEN MOULTON, for applying to gutta-percha his process for vulcanizing caoutchouc with hyposulphite of lead, to which allusion has been made in the article CAOUTCHOUC, Vol. I., p. 450. The same process is applied to a combination of equal parts of gutta-percha and caoutchouc, as to either of these alone; and when it is desired to produce a hard-cured gutta-percha, or a hard composition of gutta-percha and caoutchouc, described by the patentee as similar to horn or ivory, he adds from two to twelve ounces of calcined magnesia to each pound of gutta-percha composition, alone or combined with caoutchouc. The whole is then exposed in a close vessel to steam or dry heat of from 250° to 300°, for a period of time which will vary from two to ten hours, according to the thickness of the material and the quantity of goods introduced in one mass. The patentee adds, that after the gutta-percha goods, whether in the form of coated cloth, sheet gum, moulded, or any other article, have undergone this process, which he terms *curing*, they will be found not only impermeable to wet, but extremely tenacious, possessing the elastic property of the cured caoutchouc, and also unaffected by changes of temperature.

In December, 1856, a patent was taken by Mr. EMORY RIDER of London, for improvements in the method of vulcanizing gutta-percha; the principal novelty of which consists in the addition of one part of sulphur, or an equivalent thereof in some of its compounds, and *one part of litharge*, to sixty-six parts of the gutta-percha, prior to the exposure of the latter to

a temperature of 235° to 245°, for the purpose of expelling the volatilizable ingredients. The sulphur or hyposulphite of lead or zinc, or the artificial sulphide of lead, or other compound of sulphur employed for this purpose, is first mixed with the gutta-percha, and then thoroughly incorporated by passing the mixture repeatedly between metallic rollers heated to a temperature sufficient to make the gutta-percha very soft, and easily kneaded or worked. The mode of effecting this, which Mr. RIDER states that he has found to be most beneficial in practice, is by the employment of a machine in which the rollers work at different degrees of speed, and produce a teasing or grinding action, which he regards as of considerable importance in working the material. After being thoroughly incorporated and ground, the material is placed in a strong metal vessel, which is filled to about one-third of its capacity, so as to leave ample room for the swelling or expansion of the compound under the action of heat. It is then exposed to a temperature of about 235° to 245° for about three hours, and for this purpose the patentee prefers steam-heat, by which he is enabled to subject the gum under treatment to a greater pressure, and to obtain a more regular degree of heat than by other means. He adds, that the gutta-percha, having undergone this preliminary heating, may be vulcanized by the application of a much lower degree of heat than has been ordinarily used in that process, and that he has found a temperature of 255° to 265° to be sufficient to effect the change.

RENOVATION OF VULCANIZED GUTTA-PERCHA.—The fact that caoutchouc or gutta-percha, or compounds of these substances which have undergone the change produced by the vulcanizing process, can in that state be only very partially acted on by solvents, and with difficulty wrought by any of the usual means employed when operating upon the natural substance, renders it necessary to mould and finish the articles before they are submitted to this process, or to vulcanize them in the moulds, having previously mixed the gutta-percha with the sulphur in the kneading or masticating machine. By the process of vulcanizing, properly so called, is meant the subsequent heating, which can be applied in the act of moulding, when the articles require to be submitted to that operation.

But that very circumstance which renders it impossible to shape or manufacture gutta-percha into new forms after it has passed through the vulcanizing process—namely, the difficulty of acting on the vulcanized material either by means of heat or the usual solvents—must entail a considerable loss in the shape of waste, unless it be possible by some expedient to renovate the vulcanized gum, and restore it to its original state. It was stated in the article CAOUTCHOUC, Vol. I., p. 448, that the separation of the sulphur from that substance presented so many difficulties that it had not yet been accomplished. It may here be remarked, however, that several attempts have been made to effect this desirable object, and that, so early as in 1846, Mr. PARKES proposed and patented a method which is attended with partial success. According to this method, eight or ten pounds of the waste-cuttings, or old and worn articles, either of caoutchouc or gutta-percha, are

boiled in twenty pounds of the chloride of calcium, for a longer or shorter period according to the thickness or bulk of the substance, until, by testing a few of the pieces, it is found to be in a state to be readily united by pressure. It is then removed from the bleaching liquor, and washed, first in a hot alkaline water, and afterwards in pure water, also hot, when he states that the substance may be re-manufactured, and again submitted to either of the vulcanizing processes already described.

In January, 1856, a patent was granted to Mr. NATHANIEL SHATTSWELL DODGE, for a method which is stated to be more effective, and by which, in the words of the patentee, scraps or waste pieces of vulcanized india-rubber, or vulcanized gutta-percha—such, for example, as old shoes, railway-buffers, carriage-springs, *et cetera*—may be rendered fit to be re-used or worked up into useful articles or fabrics, *without requiring to be re-vulcanized*. For this purpose, the material to be treated, if existing in large pieces, is reduced into smaller ones, and is then placed in a vessel capable of being hermetically closed and made air-tight. To this material is now added pure alcohol—*alcohol absolutus*—and bisulphide of carbon, in the proportion of a quarter of a pound of the former and ten pounds of the latter to one hundred pounds of the material, the alcohol and the bisulphide being previously mixed together, and then poured over the material to be treated. The vessel containing the ingredients is then closed air-tight, and allowed to remain so for about two hours, more or less, at the expiration of which time the cover may be removed, when the whole, says the patentee, is found to be in a soft, plastic, or gummy state, and ready to be ground in the ordinary way of grinding such gums, for the purpose of manufacturing it into various useful or ornamental articles without repeating the process of vulcanizing. By adding a larger proportion of the alcohol and bisulphide of carbon, the gums may be reduced to a liquid state. The relative proportions of the two may, however, be varied according to circumstances, and the effect which it is desired to produce.

VARIOUS COMPOUNDS OF GUTTA-PERCHA.—In addition to that combination of gutta-percha with sulphur or its compounds, which, with the subsequent exposure of the material to a high temperature, constitutes the process of vulcanizing, a great variety of patents have been taken for combining this substance with other materials to render it softer or harder, more or less elastic, or more durable, and so to fit it for one or other of the almost innumerable purposes to which it has been proposed to apply it. To enumerate the whole of these patents in detail, so as to describe with precision the various processes and applications proposed, would both exhaust the patience of the reader and exceed the limits of this work. It is necessary, however, to give an abstract of the most important of these patented compounds and processes, to prepare the reader for a subsequent enumeration of the wonderful variety of uses to which this valuable substance has already been rendered subservient; and, in doing so, the Editor conceives that the best arrangement he can adopt is to follow the order of dates:—

Mr. HANCOCK's patent for January, 1846—the first patent taken on the subject—embraced a claim for making a compound elastic water-repelling substance, for manufacturing purposes, by mixing gutta-percha with jintawan, a somewhat similar material then recently imported from the East Indies, and also with caoutchouc, or with both, in proportions varying according to the softness, stiffness, pliancy, or extensibility which it was proposed to give to the compound. He states in his specification, that a good composition for bands or tape is formed by combining fifty parts of gutta-percha, twenty-four parts of jintawan, twenty of caoutchouc, and six of orpiment. These are incorporated together in the masticating machine, and the combination is facilitated by moistening the mass with rectified oil of turpentine, or some other solvent. The orpimented or sulphurised compound is then exposed to a heat of from 300° to 340°, for a period varying according as the temperature is higher or lower. With a heat of 300° about sixty minutes are required; while fifteen minutes are sufficient for a temperature of 340°. The required heat may be obtained either by means of high-pressure steam, or of water heated under pressure, or of hot air.

Another claim embraced in Mr. HANCOCK's first patent consisted in a method of improving gutta-percha in softness and pliancy, as also its combinations with caoutchouc and jintawan, supposing the substance, whether single or compound, to have been previously sulphurised. For this purpose, he subjects the article, whether in the state of blocks, sheets, threads, or any other form, to the action of sulphurous acid, either by exposing it to the acid in the state of vapor, or by steeping it in water impregnated with the acid, or by spreading over the article a paste made of sulphuric acid and ivory, or bone-dust, or animal charcoal, and then placing it in a steam-heated vessel or chamber.

Another method of producing the same effect—claimed also in the same patent—consists in adding to the gutta-percha and its compounds when passing through the masticating machine, and whether they are mixed or not with orpiment or any other sulphide, about ten per cent. of vegetal wax or tallow.

In October, 1847, a patent was taken by Mr. THOMAS FORSTER, for combining gutta-percha with animal charcoal, hydrate or milk of sulphur, ground whalebone, fragrant essential oils, musk, tonquin beans,orris root, or gum-benzoin, and for applying all or either of these ingredients, alone or in combination with caoutchouc or other matters, to fabrics or leather for clothing, lining for railway carriages, cart and rick covers, wrappers for goods, *et cetera*. For this purpose the gutta-percha is first cleansed or purified, and then put into a hot masticating pan with one or more of the substances above-mentioned, in the proportion of four parts of the gutta-percha to one of animal charcoal; or four of gutta-percha, two of india-rubber, and two of animal charcoal. The latter should be of the finest description, and carefully sifted through a very fine sieve. When these matters are thoroughly incorporated, a portion of any solvent is to be added—by preference, oil of coal—in such proportions as are needful for the particular fabric to be coated. The patentee found

equal weights of each to be good proportions. When the gutta-percha and solvents are well combined by heating them in a vessel enveloped in a steam-jacket, and are in a fit state to be spread upon the fabrics, Mr. FORSTER adds orris root or other perfumes in such proportions as are necessary to give the goods the desired scent; but if caoutchouc is a component part of the compound, he says it is best to use orris root, tonquin beans, musk, or gum-benzoin only, as the fragrant essential oils are apt to act injuriously upon the rubber in the course of time. For coarse goods, such as carriage covers and the like, he takes gutta-percha four parts, ground whalebone and hydrate of sulphur, each one part, and one-sixteenth part of guy mineral preservative of vegetal matter—by preference, arsenic—works the whole in a mauling pan, and afterwards spreads it upon the fabrics, with or without a solvent. If the fabrics are required to be of any particular tint, he adds to any of the above compositions the color necessary to produce it.

In forming such articles as are required to resist moisture, as buttons, tea-trays, military ornaments, *et cetera*, he first saturates the fabrics with any water-repellent matter, preferring for this purpose boiled linseed oil, dries them thoroughly in a stove, and then coats them with the first-mentioned composition of gutta-percha. In making panels for carriages, doors, boxes, *et cetera*, he uses staves of wood, deal as the cheapest, and coats them with any of his gutta-percha compositions, using one part of the composition to two of the solvent. When the solvent has thoroughly dried, he takes pieces of the required size and heats them, lays one upon the other, taking care to reverse the grain of the wood, and then presses the whole while hot, keeping the pressure upon them till cold.

The compositions he prefers for moulding without fabrics are—gutta-percha four parts, bone-charcoal two parts, and one-sixteenth part of arsenious acid; or, gutta-percha four parts, ground whalebone or the rasping of horns and hoofs two parts. If a hard composition of a light color is required, he uses gutta-percha three parts, ivory or bone-dust one part, and Cornish clay a half part. He states that a large quantity of animal charcoal or bone-dust will make these compositions much harder at the expense of their toughness. The articles he makes directly from these solid compositions are carriage and other wheels, ornamental leaves and scrolls for furniture, military and other ornaments for harness, trays, frames, cornices, leaves, and flowers. The quantity of perfumes to be used in any of these compositions must depend upon the purity of the material. He finds, however, that of orris root half a pound to every five pounds of the composition is necessary; of benzoin, two ounces to every five pounds; of the essential oils, about half an ounce to five pounds.

To finish the surfaces of fabrics or leather prepared with gutta-percha or its combinations, he coats them with transparent colors, made by combining the colors with oils or varnishes. His mode of operating is as follows:—Suppose the fabric is coated with gutta-percha, and animal charcoal or lamp-black, the color would be a dull black; to improve upon this, he takes

ten pounds of linseed oil and twenty ounces of Prussian blue, grinds and mixes, boils the whole gently until it is as thick as treacle, which is readily seen by trying a drop on a bit of glass, and when cold it will be found to be a brown transparent varnish. Apply a thin coat to the surface of the cloth, it will be dry in a few hours, and in drying will absorb oxygen and become blue, thus giving the cloth the fine color of black enamelled leather.

If other colors are required—as red, for example—the fabric should be coated with gutta-percha and vermillion. Take one pound of any oil-varnish, or pale linseed, nut, or poppy oil, previously made drying by any of the ordinary methods, and three ounces of crimson lake; grind them well together, and coat the fabric with a thin layer. If the fabric has been embossed or corked to imitate morocco leather, the result will not be a bad imitation of that article. Of course, any tinge may be produced by a similar process.

In July, 1848, Mr. ANTHONY LORIMER obtained a patent for improvements in the means of purifying gutta-percha, and for new combinations of that substance with other materials. The first part of the method claimed consists in a somewhat intricate system of knives and other machinery for slicing and kneading the gutta-percha; the second consists in combining it with burned clay, burned flint, broken articles of porcelain and earthenware, marble, Portland, Cornish, and other stones, all crushed and sifted; also, the oxides of zinc and copper, the hydrate and oxalate of lime; also a compound of lime slacked with oxalic acid dissolved in water. He uses about three pounds of acid to a bushel of lime, the acid being first dissolved in a quantity of water suitable for slacking that proportion of lime. For making soles for boots and shoes, the great object is to incorporate as much of either of the above matters, or mixtures thereof, as the gutta-percha will take up, and retain a flexible and adhesive character; but in cases where the compounds are to be subjected to strain, such as straps and bands, then smaller quantities of these substances must be combined with the gutta-percha. The gutta-percha compounds so produced may be moulded into any desired form, or pressed into sheets between rollers.

In November, 1854, a patent was taken by HENRI JULES DUVIVIER and HENRI CHAUDET of Paris, for a method of treating gutta-percha with the chloride, bromide, iodide, or fluoride of sulphur, or with the corresponding compounds of phosphorus, boron, silicon, and arsenic, or the bichlorides of tin and antimony; but of these substances the patentees prefer to employ the chloride of sulphur, although they allege that results similar to those obtained by the use of that compound may be obtained by the use of any of the other compounds above-mentioned. The process which they adopt for applying these substances is merely a modification of that vulcanizing process originally patented by Mr. PARKES. The gutta-percha is dissolved in bisulphide of carbon, the solution being made in a close vessel, and at a temperature of 86°. This menstruum, when purified by deposition, is evaporated to dryness, and another clear solution is made, to which from two to fifteen per cent. or more of chloride of sulphur.

diluted with bisulphide of carbon, is added and well mixed; or if any of the other substances before mentioned are employed in place of chloride of sulphur, then from fifteen to fifty per cent. should be employed. The patentees make the following interesting statements with reference to the properties of the resulting compounds, according to the proportions in which the ingredients are mixed:—

1. By mixing only two per cent. of chloride of sulphur, or only fifteen per cent. of the other substances, with the sirupy solution of gutta-percha, a compound is obtained which does not materially differ from gutta-percha in its properties.

2. When more than two per cent. of chloride of sulphur is employed, the compound can be extended when heated to 100° or 120°, and it remains extended when cooled, but retakes its original form when again heated; and at about 212° it agglutinates.

3. When five per cent. of chloride of sulphur is added, the compound only differs from that just described in being less softened by heat, and in being slightly elastic when cold.

4. When ten per cent. of chloride of sulphur is added, the properties of the gutta-percha are quite changed, and the compound is unaltered by a temperature of 212°.

5. When above fifteen per cent. of chloride of sulphur is added, the compound becomes horny and harder as the quantity of chloride of sulphur increases.

Articles may be formed from these compounds by pouring them as soon as mixed into metal or other suitable moulds, and there allowing them to set. In the same way the patentees cast blocks of elastic gutta-percha, which are afterwards cut up into pieces of a suitable size for rubbing out pencil marks. The compounds may also be used for glueing or attaching one substance to another, in which case they should be applied in a fluid state, and the two surfaces to be attached should be held together until the cement is quite hard. When attaching leather by this cement, the surface of the leather should be made rough. Or the process may be varied by first coating the surfaces to be attached with untransformed gutta-percha, and then wetting the surfaces with a solution of two to ten parts of chloride of sulphur in one hundred parts of bisulphide of carbon, and pressing the surfaces together till hard.

In a similar manner, articles may be coated with transformed gutta-percha, by dipping them first into a sirupy solution of gutta-percha in bisulphide of carbon, and afterwards plunging them into a bath consisting of two to ten parts of chloride of sulphur dissolved in one hundred parts of bisulphide of carbon.

When it is desired that the gutta-percha should penetrate, in place of remaining as a coating on the surface of the article, as is sometimes desirable when treating sheets of fabric, wood, leather, and similar materials; then, in place of simply dipping the article in the solution of gutta-percha, it is allowed to soak therein for twenty-four to thirty-six hours, and is moderately heated, passed between rollers, and afterwards dipped into a solution of ten parts of chloride of sulphur in one hundred parts of bisulphide of carbon.

If the articles subjected to these processes are of such a nature that they would be damaged by the acid vapors formed during the operation, the patentees state that carbonate of soda should be mixed with the solution of gutta-percha, in quantity sufficient to neutralize the acid formed.

In June, 1855, a patent was taken by P. AUGUSTIN GODEFROY for mixing cocoa-nut shells in a finely-ground or comminuted state with gutta-percha in the process of its manufacture, by which it is alleged that the following advantages are obtained:—1. Considerable economy in the manufacture; 2. Greater durability in the product, especially when applied to the manufacture of boot-soles, clogs, goloshes, and other articles exposed to much wear; and 3. Greater elasticity, with the power of resisting a higher temperature than ordinary gutta-percha. By grinding machinery fitted for the purpose, the patentee reduces the cocoa-nut shells to powder of three degrees of fineness. The first, or finest quality, he employs for mixing with gutta-percha intended for tubing, for an insulating coating to telegraph wires, and such like purposes; the second or coarser, for driving-bands, boot-soles, ornamental mouldings, *et cetera*; the third, or coarsest quality, for lining ships, for hut linings, for covering floors and walls, and other similar purposes. The Editor can see no objection to a little adulteration of the gutta-percha for the latter two modes of its application; perhaps the admixture of cocoa-nut shell might even, in some respects, increase its adaptation for these and other purposes; but he doubts how far the same admixture would improve the quality of gutta-percha as an insulator of electricity, or as an admixture in the composition of tubes intended to resist acids, and to be impermeable to moisture.

A communicated patent, dated November 27, 1855, was taken for improvements in the manufacture of india-rubber and gutta-percha, by mixing with these materials calcined shells, or other cheap substances of a like nature, so that when afterwards vulcanized and rendered hard by being subjected to a high degree of heat, the material may be applicable to the manufacture of bobbins, cylinders, rollers, racks, ratchet-wheels, and other parts of spinning machines. Though gutta-percha is embraced in the patent, india-rubber seems to be the substance to which the admixture of calcined shells is considered most applicable.

In August, 1856, a patent was taken by Mr. CHARLES GOODYEAR for an improvement in combining gutta-percha with asphalt or pitch. The method previously in use was, to combine gutta-percha and asphalt by masticating the two together, in the same manner as gutta-percha and india-rubber are combined in the knocading machine. Mr. GOODYEAR's improvement consists in effecting the combination by the aid of hot water, by which the two matters are softened, and made comparatively fluid. For this purpose a close vessel is used, into which the substances are introduced, mixed with a quantity of water, and the temperature is raised to such a degree as to melt both; after which they are to be well stirred, to blend them together. He considers that this melting of them together effects the most perfect combination. And having been thus

thoroughly blended in a fluid state, they may, when desired, be further combined with sulphur, also with india-rubber and other matters; and the various compounds thus produced are, when required, subjected to high temperatures, in order to produce the change which is known as *vulcanizing*.

WATERPROOFING AND DEODORIZING.—Mr. HANCOCK's patent of January, 1846, embraced a method of producing varnishes which might be applied to the waterproofing of leather or cloths; and by applying them either alone or mixed with coloring matters to gutta-percha or its compounds, or to articles made from them, they might have a fine glossy exterior given to them, and the smell of any ingredients which might have been mixed up with them, such as that of the sulphur in vulcanizing, would be effectually removed. For this purpose he mixed gutta-percha and caoutchouc, or gutta-percha and jintawan—using the substances indifferently, so far as regards the proportion one bears to the other—with sulphur or orpiment, or other sulphide, in the proportions that are usually employed for vulcanizing, with about eight to ten parts of animal or vegetal wax, or animal or vegetal fatty matter, and then dissolved in rectified spirits of turpentine, and evaporated. He adds that these varnishes, mixed with colors, may be used for the purpose of painting or printing cloth, leather, or any other fabric, and will be found very useful as waterproof cements, particularly in combining gutta-percha and its compounds with silk, cotton, and other textile fabrics.

In November, 1853, a patent was taken by Mr. JOSEPH FRY for improvements in preparing solvents for india-rubber and gutta-percha, and in rendering waterproof fabrics free from smell. With reference to the first claim, it is stated in the specification, that previously the solvents employed for india-rubber and gutta-percha had been distilled and rectified before their application; but it had been found by the patentee that these solvents are improved if india-rubber or gutta-percha be combined with the solvents before distilling them, or be present in a certain proportion during that operation. The solvents usually employed for waterproofing purposes are turpentine and coal-naphtha, or coal-oil. In proceeding to distil one or other of these, he introduced into the still, along with the solvent, from four to six ounces of the india-rubber or gutta-percha to each gallon of the liquid; and he affirms that the product distilled over is materially improved for the purpose of its subsequent use in dissolving larger quantities of the same substances, while the residue in the still will be found useful for fabricating common or inferior articles, and for waterproofing coarser and lower-class cloths. Or, by another method, the crude solvent might be first distilled without india-rubber or gutta-percha being present, and afterwards be combined with india-rubber or gutta-percha, and again distilled or rectified. The latter mode of treatment is regarded by the patentee as producing the best result.

The second part of the claim, which has for its object the removal of the odor of articles fabricated of india-rubber or gutta-percha in which solvents have been used, consists in subjecting the waterproof cloths, whether before or after being made up into garments or

other articles, to the action of steam in a close chamber or steam-chest; and for this purpose the patentee does not find it necessary to employ steam of a much higher pressure than that of the atmosphere. A longer or shorter time is required to remove the odor of the solvent, according to the amount of it that has been present.

DECOLORING GUTTA-PERCHA.—In February, 1853, a patent was taken by Dr. NORMANDY for decoloring gutta-percha by means of animal charcoal, embracing also a novel method of forming it into sheets and balloons. The gutta-percha to be operated upon by this process is previously purified as much as possible by cutting, and pressing or kneading it in hot water. It is then exposed at a gentle heat to the action of some volatile solvent, such as essence of turpentine or benzol, but preferably of bisulphide of carbon, in which latter case no heat should be applied. One part by weight of gutta-percha dissolved in about twenty parts of solvent, yields a brown, turbid, sirupy mass, which is clarified and partly decolorized by first allowing it to stand till the heaviest particles subside. The supernatant liquid, still much colored, is thoroughly purified by filtration through animal charcoal; it is then put into a still provided with a refrigerator, and if it be desired to obtain the gutta-percha in a solid state, the distillation is continued to dryness. But to obtain sheets, or to make balloons, shades, and various other forms of gutta-percha, the patentee proceeds as follows:—He takes the purified solution of gutta-percha in bisulphide of carbon, and pours a certain quantity of it into a vessel—for example, a glass cylinder stopped at one end. He then inclines the vessel, and turns it in every direction, until its sides are completely and evenly coated over internally by the solution, and then allows the excess of liquid to drain off, by holding the glass cylinder with its mouth downwards. In a short time the bisulphide of carbon volatilizes completely, leaving the inside of the glass covered with a film or thin lining of gutta-percha, which loosens by its contraction in drying, and may then be readily extracted. Care must be taken, however, not to touch the cylinder with a warm hand, for the gutta-percha will adhere to the glass at the points which have been thus warmed. If the part which was in contact with the bottom, or closed part of the cylinder, be now cut off, a cylinder of gutta-percha, open at both ends, is obtained, and this being cut longitudinally, will form a sheet. Thin semi-transparent balloons, or almost any other form, may be produced in the same way, since the solution of gutta-percha will necessarily take the form of the vessel into which it is poured. When, however, the gutta-percha membrane has to be removed through a small aperture—which happens when the sirupy liquid has been poured into a bottle, or glass balloon, or mat-ras—some contrivance must be resorted to, as that of introducing into the vessel a tube, by means of which the air in the vessel can be sucked out, either by the mouth, or with a syringe; the gutta-percha membrane will thus be made to collapse and recede from the sides of the vessel, after which it may be easily removed. It is evident that the more viscid the solution, the thicker will be the membrane obtained.

DYEING OF GUTTA-PERCHA, AND ITS COMBINATIONS.—A method of coloring articles formed of gutta-percha, or coated with a varnish of that substance, has been just stated, in connection with Mr. HANCOCK'S method of waterproofing and deodorizing. It is obvious that the same varnish which excludes moisture, and confines the odor of the solvent, may be mixed with colors, and will thus form a pigment of any required tint. This process may be termed painting, or color-varnishing; but in Mr. PARKES' patent for March, 1846, was embraced a claim for *dyeing* caoutchouc or gutta-percha, alone or in combination, and afterwards, when desired, treating those matters by vulcanizing agents, either in solution, or by the dry method. To dye caoutchouc, or gutta-percha, or their compounds, he boils them from a quarter to half an hour in the following preparations:—

Black.—One pound of sulphate of copper dissolved in one gallon of water, with one pound of caustic ammonia, or chloride of ammonium. Or—one pound of sulphate or bisulphate of potassa, and half a pound of sulphate of copper, with one gallon of water.

Green.—One pound of chloride of ammonium, half a pound of sulphate of copper, two pounds of caustic lime, and one gallon of water.

Purplish.—One pound of sulphate or bisulphate of potassa, one quarter of a pound of sulphate of copper, and one quarter of a pound of sulphate of indigo. Of course, the depth of color may be varied by varying the proportions of the ingredients.

Or the following colors may be applied directly:—

Blue.—Victoria blue and ultramarine.

Red.—Vermilion, carmine, or rose-lake.

Green.—Brunswick green, or acetate of copper.

Yellow.—Chrome yellow, or oxide of uranium.

White.—The color known as satin white. Mr. PARKES prefers generally to use this as a ground for the hues above-mentioned. *The coloring processes must precede the vulcanizing of the material.*

METALIZING.—In Mr. HANCOCK'S patent of February, 1847, was embraced a method of improving the quality of gutta-percha, both in its natural and vulcanized state, by exposing it for a minute or two to the action of binoxide of nitrogen, obtained by the usual method of dissolving a metal, such as zinc, copper, or mercury, in nitric acid, or by immersing it in a boiling and concentrated solution of chloride of zinc, for a period varying from one to five minutes, according to the strength of the solution. In either case, the materials are afterwards well washed in some alkaline solution, or in soft water. Gutta-percha which has been thus treated, and whether vulcanized or not, is stated by the patentee to become exceedingly smooth to the touch, and of a lustre approaching to metallic.

SUBSTITUTES FOR GUTTA-PERCHA.—In December, 1853, a patent was granted to STANISLAS T. M. SOREL, of Paris and London, for certain improved compositions to be employed as substitutes for caoutchouc and gutta-percha. These compositions, though termed substitutes, are simply combinations of gutta-percha with other bodies, resembling in most cases those already mentioned as patented by other individuals for the same purpose. This will be at once seen from the following

ingredients and proportions employed for his principal mixture:—

	Parts by weight.
Colophony,.....	2
Pitch or bitumen,.....	2
Resin oil,.....	8
Hydrated lime,.....	6
Water,.....	8
Pipe-clay, or other like argillaceous earths,.....	10
Gutta-percha,.....	12

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The patentee prepares the composition in a copper, heated by any suitable means. He first introduces into the vessel colophony, bitumen, or pitch, and resin oil, and agitates the mixture with a stick, or spatula, until the former two are dissolved. He then adds slacked and broken hydrate of lime of the consistence of molasses, continuing to agitate and heat the mixture, and when the latter is completely liquefied he introduces the gutta-percha, cut into small pieces. The agitation is continued till the gutta-percha is dissolved, when argil is introduced, either powdered or mixed with water, and well incorporated with the mixture. An excess of water is then added, and the whole is heated to ebullition. The matter is now separated and kneaded in water, then withdrawn from the copper and again heated, and passed several times between the rollers of a rolling machine to render it homogeneous, when it is ready to be employed.

The colophony may be replaced by other resins, as burgundy pitch, or gum-copal. The argillaceous earth may be entirely suppressed in the composition. To render the latter more tenacious, he increases the quantity of gutta-percha; and to augment still more its tenacity, and render it a little elastic, he adds a small quantity of natural or vulcanized caoutchouc, cut up, like the gutta-percha, into small pieces. To render the composition more completely waterproof, he adds about five per cent. of bees' wax or stearic acid. It may be colored with smoke-black, or other coloring matters.

Subjoined are three combinations, in the first of which the colophony is replaced by pitch; in the second, both the resin and resin oil are superseded; and in the third, pitch is replaced by coal-tar from the gas-works:—

	I.	II.	III.
Pitch,.....	8	12	—
Resin oil,.....	4	—	—
Coal tar,.....	—	—	12
Slacked hydrate of lime,.....	6	6	6
Gutta-percha,.....	16	16	16
	34	34	34

Argil may be added to the above three compositions. They are stated by the patentee to be applicable for replacing caoutchouc and gutta-percha in their principal applications, and especially for waterproofing stuffs, and the manufacture of tubing, of driving-straps, waterproof boots and shoes, bobbins and cylinders for spinning machinery, capsules for stopping bottles, and other like articles. They may likewise be moulded for making vases, and other ornamental articles. For giving the composition greater tenacity, fibrous materials, such as cotton, wool, hemp, cord hair, and leather

waste, may be added. When properly rolled into sheets, it may be lined or covered with thin sheets of natural or vulcanized caoutchouc by means of a rolling machine, or by sticking them together with a solution of caoutchouc or gutta-percha, or any other suitable adhesive agent. These double sheets may be employed for the upper leathers of waterproof boots and shoes. The soles may be either of waterproofed leather, of gutta-percha, or of wood.

ADULTERATIONS.—From the list of patents which have been given for mixing or combining gutta-percha with other substances, including caoutchouc, pitch, pipe-clay, vegetal wax, calcined bones, coal-tar, lime, sulphur, cocoa-nut shell, Portland stone, and an almost infinite variety of other materials, all of which are assumed by the respective patentees to peculiarly adapt the resulting compound for certain specified applications, it may seem unreasonable to brand as adulterations the admixture of ingredients which are added by legal sanction for certain avowed purposes. On this extreme principle even the process of vulcanizing, which imparts to caoutchouc and gutta-percha more than half their value, would be a sophistication; for it presupposes the admixture of the article with sulphur, or some of its compounds. Allowing, therefore, that gutta-percha may be too often adulterated, and deteriorated for all practical uses, under patent authority, while, on the other hand, the fact is undeniable that by certain admixtures and combinations the qualities of the compound are improved for certain purposes, the Editor will confine himself to those adulterations which are practised by the native Malays and Chinese traders, and in consequence of which an impure or inferior article is palmed on the European importer.

The fact that the native Malays often introduce stones, earth, and other impurities, into the blocks of gutta, to increase their weight, has been already noticed, and may also be left out of consideration, as these impurities are often too easily detected, to the injury of the machinery of the manufacturer. Such impurities are also readily eliminated in the process of purification. But the case is otherwise, when, as frequently happens, the gutta-percha is mixed with other gums of an inferior character. The chief trade in the article is carried on by the Chinese, who adulterate it with the valueless juice of a tree called *Gedah Malabeöya*, which they import from Palembang. By this admixture various sorts of gutta-percha are obtained, which differ considerably in price. Among several samples examined by M. ADRIANI, one was in cakes of five to six inches thick, and was darker on the outside than in the interior; another was of a very loose structure, and was much contaminated with small stones, but agreed in color, which was in general a flesh-red, with the former; a third sample was white, slightly inclined to brown. This last piece had been removed as an impurity from a large block of gutta-percha, but was found to be in quality perfectly equal to the best gutta, and was afterwards rolled out in the manufactory of MUNNICH, BECKE, and Co., into sheets of the thickness of paper, for address cards for that firm. The same chemist obtained a sample of

the *Gedah Malabeöya*, imported from Palembang, and also a sample of gutta-percha adulterated with that substance. The *gedah*, which seemed to be also an inspissated milky juice, was imported in the form of plates, of about an inch in thickness, of a greyish color, somewhat clammy to the touch, and brittle when dried. When cut, it was found of a dirty white color, and contained many impurities. Like gutta-percha, it was dissolved by chloroform. The vessel in which it was contained emitted, on being opened, a disagreeable acid smell. Treated like gutta-percha, and purified by hot water, it was much darker than the raw substance, and often quite black; the smell was equally offensive, and its consistency similar to that of wax or glaziers' putty. The gutta-percha adulterated with the *gedah* was of a loose texture, of a more greyish color, and of a smell different from that of genuine gutta. In warm water the *gedah* became soft and sticky; treated with boiling water, it formed a neutral milky liquid, which was precipitated by alcohol. When boiled with alcohol it became glutinous, the alcohol extracting a white fat, resembling wax and resin; ether extracted also resin. Being dissolved in chloroform and filtered, a black coloring substance remained behind, which could not be dissolved by the usual solvents, and was burnt without leaving a residue. It appeared to be nothing else but soot. The *gedah* melts at 170°, and becomes decomposed only at a much higher temperature, when dark-colored oils are distilled off.

USES AND APPLICATIONS.—From several processes described in connection with the manufacture of gutta-percha, and from the list of patents enumerated under the head of its combinations, *et cetera*, the reader will have seen that the substance admits of a vast variety of applications; and, indeed, the mere consideration of its singular and valuable properties is sufficient to show that the only bar to its almost indefinite extension into the arts and uses of life is the considerable price of the article, arising from its necessarily limited supply compared with the great demand for it. Its chemical and other properties have been already stated, but in now proceeding to give a more extended list of its applications, it may not be out of place to remark that these will be found chiefly to depend on the following peculiarities:—

1. Its capacity of being moulded by gentle heat and pressure into any required form, and of retaining this impressed form when cold, with extreme tenacity.
2. Its pliability at common temperatures.
3. Its impermeability to water and other fluids.
4. Its power of resisting not only the solvent action of common liquids, but even the corrosive action of most acids, of caustic alkalies, and alcoholic liquors.
5. Its valuable property as an insulator or non-conductor of electricity, in which respect it ranks second to no other known substance.
6. Its singular acoustic properties, as a conductor of sound.
7. Its capacity of combining with sulphur or its compounds, and being vulcanized like caoutchouc, so as to be unaffected by considerable changes of temperature.
8. Its aptitude for uniting with various other substances in any required proportion, so as to produce

compounds combining remarkable hardness with a certain amount of elasticity.

9. Its power of receiving and retaining the sharpest and finest impressions from the die or mould.

10. Its great durability at common temperatures, and under almost all agencies.

To these properties, separately or conjointly, may be traced its peculiar fitness for the following applications, namely: For a protection to underground and submarine telegraph-wires—a purpose for which it is not less fitted by its pliancy and its resistance to moisture than by its high insulating power; for replacing the cylinder or disc of electrical machines; for insulating handles and other electrical apparatus; for tubes to convey not only cold water, but acids, alkalies, and other corrosive liquids; for bath-cisterns, buckets, bottles, or other vessels; for lining acid and alkali cisterns formed of wood; baths for photographic purposes, and different laboratory apparatus; sieves and pumps for acid and alkaline liquors; funnels, siphons, valves, and stop-cocks for corrosive solutions; conversation tubes for mines, ships, warehouses, or railways; stethoscopes and other surgical instruments; driving-bands for all kinds of machinery; rollers, bobbins, *et cetera*; boot-and shoe-soles—one of its most extensive applications; water-proof clogs for dyers or maltmen; horse-trappings; water-proof cases for charts, maps, arms, and such like; noiseless rings for bed and window curtains; cords for window-sashes and blinds; clothes-lines; whips; water-proof portmanteaus; hats for miners, sailors, carriers, *et cetera*; moulded objects of every description, as fancy baskets, bread-trays, ink-stands, watch-stands, clock-cases, medals, picture-frames, buttons, flower-pots, and various similar applications.

The author of the Jury Report on the manufactures from gutta-percha in the Great Exhibition, says:—It is especially in the fabrication of articles for maritime use that gutta-percha—resisting, as it does, the action of water, and especially of brine—appears to be the best adapted. Buoys of every description for anchors, nets, *et cetera*, have been made of it; sailors' hats, speaking trumpets, and the like. It may be added that even fish-nets are formed of gutta-percha cord. It will be seen from the preceding enumeration of uses, that the decorative art has also taken large advantage of the plastic properties of gutta-percha. Various articles of furniture, the prices of which are so much enhanced by carving, are capable of being reproduced by means of pressure, and thus multiplied at a comparatively low price. Writing-tables, work-baskets, *et cetera*, can be produced in gutta-percha, and thus made to combine the threefold advantage of lowness of price, elegance of form, and absence of fragility. In the London Gutta-Percha Company's Works are made every day a great quantity of mouldings, friezes, panels, leaves, and articles of every description. These, combined by the decorator, and covered with gilding, which gutta-percha takes in perfection, are, in the manufacture of picture-frames, and in the decoration of furniture, capable of superseding the carving upon wood, which is so costly, or papier-mâché and carton-pierre, which present the defect of great fragility.

Bronze articles have also been reproduced in a fel-

icitous manner. At the Great Exhibition, the West Ham Gutta-Percha Company, represented by Mr. HANCOCK, exhibited, among various other objects, a beautiful group representing a boar-hunt, covered with a metallic coating in imitation of bronze. The author of the Jury Report remarks, that the clearness of the edges and the purity of the forms which gutta-percha receives in the mould, make it easy to understand how this substance has been found capable of being used for making galvano-plastic moulds, and how some experiments have been tried for the purpose of substituting gutta-percha in the process of stereotyping, for the metal with which at the present day the pages of illustrated books are multiplied. Stereotype plates of gutta-percha, with specimen impressions, were actually exhibited by the London Gutta-Percha Company, in connection with a large unfinished machine, intended for printing therewith on endless paper, which was also to be cut and folded before leaving the machine, the gutta-percha types not requiring the paper to be damped. It does not appear, however, that this application of gutta-percha has been brought into general use. Moulded into the form of a jawbone, it has been found capable of holding together artificial teeth, and thus advantageously superseding those settings in gold which were so costly, and which, on account of their absolute rigidity, presented much inconvenience. The solution of gutta-percha in oil of tar and other solvents, which, by their evaporation, leave the gutta uninjured, can be made use of to obtain sheets of extreme thinness, which have begun to be extensively used in surgery. But, apart from its use as a covering for submarine telegraph wires, and its common application as a substitute for leather soles, it is more especially to the manufacture of tubes and chemical utensils for the conveyance and conservation of acids, *et cetera*, that gutta-percha seems calculated to render the greatest services.

STATISTICS.—The imports of gutta-percha into the United Kingdom in 1850, amounted to one thousand two hundred and fifty tons. The prices vary, according to the supply and demand, from fourpence to one shilling and fourpence per pound—average, eightpence—showing the aggregate value of the above imports to be equivalent to ninety-two thousand five hundred and fifty pounds sterling. The article is manufactured in London, Manchester, and Liverpool.

HYDROCYANIC ACID.—*Acide prussique*, French; *Berlinerblausäure*, *Hydrocyansäure*, German; *Acidum hydrocyanicum* vel *Borussicum*, Latin.—This important compound—which, from its animal origin, has also been named *zootic acid*, and the poisonous properties of which are, unfortunately, so well known—was first isolated by SCHEEL. DIESBACH and DIPPEL, in 1704, discovered Prussian blue. Forty-eight years afterwards, MACQUER found that lime-water resolved this substance into *calx of iron—sesquioxide*—and a *combustible coloring matter*, which he could not separate, but which combined with potassa, forming *phlogisticated potassa*—ferrocyanide of potassium. GUTTON MORVEAU concluded in 1772 that this principle had acid properties. In the year 1782, SCHEEL succeeded in preparing the aqueous solution of *prussic acid*, which

he said was composed of ammonia, acid of air, and phlogiston. BERTHOLLET, in 1787, described it, in similar terms, as consisting of carbon, hydrogen, and nitrogen. PROUST and LITNER discovered several of its compounds, and the latter is said to have procured anhydrous hydrocyanic acid by the action of hydrochloric acid upon cyanide of mercury, but, being unable to condense the vapor, he pronounced it to be a permanent gas. GAY-LUSSAC, however, in 1811, effected its liquefaction, determined the relative proportions of its ultimate elements, and led the way to the intimate knowledge and useful application of many of its compounds.

SOURCES AND PREPARATION.—Hydrocyanic acid exists, ready-formed, in many vegetal substances; and is generated in many others, in which it was formerly believed to pre-exist, by the various methods which were devised for its extraction. The kernels of bitter almonds, plums, peaches, apricots, and cherries, the leaves and more tender branches of the peach, the leaves of the Portugal and cherry laurel, and many portions of other vegetals belonging to the sub-orders *Pomæ* and *Amygdalæ*, when steeped in water for a considerable time and then distilled, yield hydrocyanic acid. According to several authorities, amongst whom are LIEBIG and WÖHLER, the formation of the hydrocyanic acid during the immersion of the vegetal substances in water, is caused by the action of the *emulsin* upon the *amygdalin*—both of which they contain—as a ferment, decomposing the latter into grape-sugar, bitter almond oil, and hydrocyanic acid—the latter two passing over in the subsequent distillation.

It is now generally received that it is only in the more moist of such vegetal structures that the acid is ready-formed. There have been adverse opinions with regard to its presence in the leaves of the cherry laurel; GUIBOURT and LEPAGE maintaining that it is formed during their immersion, while WINCKLER holds that bitter almond oil containing hydrocyanic acid does really exist in the fresh leaves in minute quantity, which he believes varies with the amount of water present, disappearing entirely when the leaves are exsiccated.

Hydrocyanic acid is produced in many ways. According to FOWNES, when nitrogen gas is passed over a mixture of equal parts of pure sugar, charcoal, and carbonate of potassa in a porcelain tube at a red heat, carbonic oxide, and subsequently nitrogen, pass off; cyanide of potassium and a carbonaceous mass remaining. When ERDMANN and MARCHAND repeated this process with pure materials, and at a moderate red heat, no cyanide was formed; and even when the temperature was raised to such a degree that vapors of potassium were carried off with the carbonic oxide, they could discern doubtful traces only: on employing carbonate of potassa containing sulphate, the presence of sulphocyanide of the alkali was evident. WÖHLER states that the production of cyanide of potassium from sugar-charcoal, carbonate of potassa, and nitrogen, is indubitably ascertained, but it is required that the nitrogen should be at a red heat, and that the temperature of the tube and its contents should be such that potassium is volatilized.

DEAROSS has observed, that when nitrogen gas is

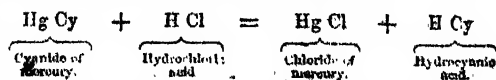
passed through a mixture of wood-charcoal and carbonate of potassa, heated to redness, a small quantity of cyanide is generated; but as wood contains albuminous matter, and its charcoal is not entirely free from it, the nitrogen might either wholly or in part emanate thence.

GMELIN, citing the experiments of RIEKEN,—in which carbonate of potassa mixed with charcoal obtained from the purest white sugar, and heated in a current of nitrogen gas, at a temperature sufficiently high to reduce potassium, was completely converted into cyanide of the alkali-metal; in one case so effectually that the cyanide did not even effervesce with acids—and taking into consideration the fact, that when a mixture of potassium or antimonide of potassium with charcoal is heated to full redness in a current of nitrogen, not a trace of cyanide of potassium can be detected,—concludes that this formation of cyanogen requires not only the presence of free potassium, but at the same time a temperature high enough to separate potassium from its oxide.

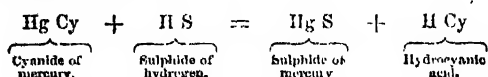
When blood, hoofs, horns, and many animal tissues are ignited with carbonate of potassa; when blood, fats, sugar, gum, starch, and many organic bodies, both nitrogenous and free from that element, are subjected to distillation with nitric acid; and in many other instances, and by other means, is hydrocyanic acid produced. PERRIRA mentions the statement that cheese, when exposed to the action of water and the sun, disengages ammonia, and when treated in this state with alcohol, yields traces of hydrocyanic acid.

Examples of the formation of hydrocyanic acid having been given, it now remains to pass on to its preparation. Many methods having this object in view have been devised; some intended to produce the acid anhydrous, others, in a dilute state. The former modes will first be noticed, commencing with that of GAY-LUSSAC, which is as under:—

Into a perfectly clean tabulated glass retort, introduce a quantity of finely-powdered cyanide of mercury, and then add rather less than the same weight of hydrochloric acid, having a specific gravity of about 1.2. Next adapt to the beak of the retort, in a horizontal position, a glass tube, about half an inch in diameter, and two feet in length. One third of this, at the end next the retort, is filled with pieces of marble, for the purpose of retaining any hydrochloric acid which may pass off with the hydrocyanic acid. To the remainder of the tube fragments of fused chloride of calcium are supplied, which absorb the aqueous vapor. To the outer extremity of this purification tube is adapted a small receiver, surrounded with a freezing mixture. The hydrocyanic acid is expelled by means of heat; but it is advisable not to raise this very high, as, in that case, too much hydrochloric acid might be evolved, and not only is this a source of inconvenience, but, by the disengagement of much carbonic acid from the marble, hydrocyanic acid may be carried off. The use of too large a quantity of hydrochloric acid is, for the same reason, to be avoided. The reaction in this case is thus represented:—

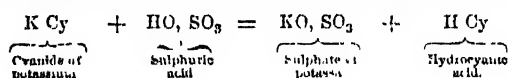


By VAUQUELIN's process the cyanide of mercury is carefully placed in a long glass tube, terminating, at one extremity, in a small receiver surrounded by a freezing mixture, and having attached to the other end a proper apparatus for the supply of pure dry sulphide of hydrogen; this gas, on passing over the metallic cyanide, liberates its acid, and unites with the mercury to form sulphide; thus:—



The whole of the cyanide of mercury may be decomposed by gently heating the tube, while the gas is still passing through it; but it is better to leave a little of the metallic cyanide undecomposed, the product of the operation being thus preserved from contamination with the sulphide of hydrogen.

The last mode of procedure which it will be requisite to describe here is that of TRAUTWEIM. Fifteen parts of finely-powdered ferrocyanide of potassium are distilled at a gentle heat with nine parts of sulphuric acid, previously diluted with an equal weight of water; the distillate is collected in a well-cooled receiver, containing five parts of pure chloride of calcium, broken into small pieces. When the hydrocyanic acid has accumulated in sufficient quantity to cover the chloride of calcium, it is poured off into a well-stoppered glass vessel. The cyanide of potassium of the ferrocyanide is decomposed as in the former two processes; thus:—



For medical purposes, hydrocyanic acid is always employed in a dilute state, and as the means for directly obtaining this are preferable and more certain than that of letting down the anhydrous acid with water, many have been devised. The London College directs that seven drachms of sulphuric acid be mixed with four fluid ounces of water, and when cooled put into a retort; next two ounces of ferrocyanide of potassium are dissolved in ten ounces of water, and added. Eight fluid ounces of water are then placed in a cooled receiver, and heat being applied to the retort, six fluid ounces of acid are distilled over. Lastly, to this dilute acid are added six more fluid ounces of water, or so much that one hundred grains of the acid are entirely thrown down by 12.59 grains of nitrate of silver. Hence, it contains two, or, more exactly, 1.92 per cent. of real hydrocyanic acid.

The dilute acid of the Edinburgh College contains, according to SQUIRE, 3.98, or, according to Dr. CHRISTISON, 3.3 per cent. of anhydrous acid. The Dublin College has not fixed the strength of the acid prescribed in its Pharmacopœia. SQUIRE represents it to contain rather more than two per cent. of dry acid.

EVERETT, in 1835, proposed an entirely different plan for at once preparing the dilute acid. Dr. PEREIRA characterises it as yielding an acid of uniform strength, and as being available when the acid is required for immediate use. It consists in decomposing forty grains of cyanide of silver, with forty minims of dilute hydro-

chloric acid—specific gravity 1.129—made up to a fluid ounce with water.

Dr. CLARKE has suggested another process:—

Eight and a quarter parts of cyanide of potassium are dissolved in one hundred of water, and to this solution is added another of eighteen and a half drachms of crystallized tartaric acid in twenty of water. Bitartrate of potassa is thus precipitated, while the supernatant fluid contains about 2.8 per cent. of hydrocyanic acid, together with traces of bitartrate of potassa held in solution.

Again, a known quantity of cyanide of mercury is dissolved in water, and a stream of sulphide of hydrogen passed through the menstruum, which is then removed from the metallic sulphide by filtration. VAUQUELIN directs that the excess of sulphide of hydrogen should be thrown down from the solution by means of carbonate of lead. According to BRANDE, it is difficult to obtain a clear and colorless solution by this process without the addition of a drop or two of hydrochloric acid.

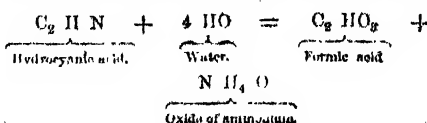
COMPOSITION.—It has already been stated in the introductory portion of the present article, that BERTHOLLET ascertained that the ultimate elements of hydrocyanic acid were carbon, hydrogen, and nitrogen. GAY-LUSSAC, in 1825, verified this, and, succeeding in obtaining the acid in an anhydrous state, determined the relative proportions of its constituents, with the following results:—

	At weight	Centesimally.
2 Eqs. Carbon,.....	12	44.43
1 Eq. Hydrogen,.....	1	3.70
1 Eq. Nitrogen,.....	14	51.85
1 Eq. Hydrocyanic acid,....	27	100.00

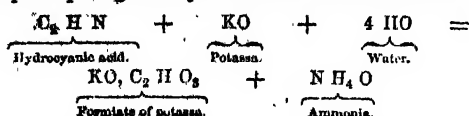
Symbol:— $\text{C}_2\text{H N} = \text{H Cy}$.

PROPERTIES.—At ordinary temperatures, anhydrous hydrocyanic acid is a clear, limpid fluid, possessing a strong penetrating odor—similar to that evolved when bitter almonds are bruised—and an acid, somewhat bitter taste. It faintly reddens blue litmus paper, but the tinge disappears as the acid evaporates in the air. It is so volatile, that when a drop is placed upon a glass plate, it freezes by the rapidity of its own evaporation. With water or alcohol it unites in any degree. Its specific gravity at 45° is 0.705, and at 64° 0.696. It boils at 79° or 80°. It congeals at 5° into a fibrous mass, having a great resemblance to crystallized nitrate of ammonia. SCHULTZ states that the perfectly anhydrous acid is still fluid under 0°, and that the solidification at 5° is owing to the presence of water.

Hydrocyanic acid is decomposed with facility under the influence of light, ammonia being generated, and a brown substance, not hitherto examined, deposited; this transformation is prevented by the presence of a small quantity of a mineral acid. Concentrated sulphuric, nitric, and hydrochloric acids decompose it, when water is present, into formic acid and oxide of ammonium, the elements of which it contains:—



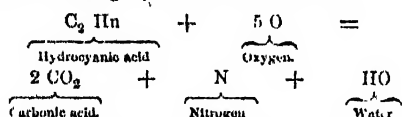
According to PELOUZE and GEIGER, the same decomposition of hydrocyanic acid into formic acid and ammonia is produced by the action of the fixed alkalis at elevated temperatures, probably in consequence of the predisposing affinity of the latter for formic acid:—



LIEBIG has found that when hydrocyanic acid is mixed with sulphide of ammonium, and the liquid heated till its color is destroyed, sulphocyanide of ammonium is formed, and this, giving immediately a blood-red hue with salts of sesquioxide of iron, forms the basis of a most delicate test for the acid, which is said to be distinctly recognizable, even when only the three thousand nine hundred and thirtieth part of a grain is present in the solution.

With nitrate of silver, hydrocyanic acid gives a precipitate, soluble, on boiling, in nitric acid; when with potassa, then a mixture of a proto- and sesqui-salt of iron, and, subsequently, an excess of hydrochloric acid are added to it, whether it is in the dilute or anhydrous state, Prussian blue is formed.

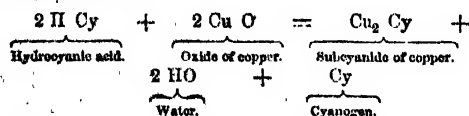
Both the anhydrous acid and its vapor are readily combustible, burning with a ruddy flame. The vapor, according to GAY-LUSSAC, has a density of 0.9476; when mixed with oxygen, it may be exploded by the electric spark, each volume of the former requiring for perfect combustion five of the latter. The products of this metamorphosis are—two volumes of carbonic acid, one of nitrogen, and one of water:—



The vapor mixed with hydrogen is, according to GAY-LUSSAC, but imperfectly decomposed by a succession of electric sparks, the gaseous compound depositing a small quantity of charcoal, and perceptibly increasing in volume. GMELIN remarks, that this expansion is not very easy to account for, unless it be due to the formation of carbonic oxide, or hydrogen arising from the presence of water.

Potassium heated in the vapor of the acid unites with the cyanogen and liberates hydrogen.

According to GAY-LUSSAC, hydrocyanic acid and hydrogen slowly produce, with oxide of copper, gaseous cyanogen and water, subcyanide of the metal probably being formed:—



The same authority asserts, that binoxide of manganese will absorb a mixture of hydrocyanic vapor with hydrogen gas, without separation of cyanogen.

PHYSIOLOGICAL EFFECTS, *et cetera*.—Although any notice, however brief, of the physiological effects of hydrocyanic acid may appear to be irrelevant here, as

belonging more properly to medicine, yet the Editor conceives that, without alluding to it, this article would not be complete, and it may have its uses. For most of the information on the subject he is indebted to Dr. PEREIRA.

Hydrocyanic acid is poisonous to the vegetal as well as to the animal kingdom. When the stems of plants, possessing irritability, are immersed in the acid, they lose this property. It prevents the milk of lactescent plants from leaving its cells, and deprives seeds of their germinating power.

Experiments have been made on animals generally, from the *mammalia* down to the *infusoria*, with hydrocyanic acid. The effects appear to have been similar in nearly every instance, the animals being convulsed, and losing sensation and voluntary motion.

According to GRAY, however, some larvæ of the *musca* remained uninjured after two or three days' immersion in the acid.

Rabbits, dogs, *et cetera*, are deprived of life by it in a few seconds, whether it is administered to them internally in the fluid form, or inhaled in the state of vapor. Even when a drop is placed on the throat or eye of a dog, death occurs in a very few moments.

It was first introduced into medicine about the year 1806 by the Italian practitioners, BORDA, BRUGNATELLI, and RASORI. Its use in England was much furthered by the investigations of Drs. A. T. THOMSON and ELLIOTSON in 1820 and the subsequent year. It has been tried as a remedial agent in many affections of the pulmonary organs, in derangements of the nervous system, in hydrophobia, as an anodyne, and as an anthelmintic, with questionable success; and it is now employed only for alleviating disorders of the stomach. The dose of course varies with the kind of acid employed. Of the acid prepared according to the London Pharmacopœia, two to seven minims may be administered. One to four minims of the acid of the Edinburgh College, or one to five minims of the Dublin preparation, are accounted a dose.

When given in medicinal doses, cautiously increased, the following effects may, according to Dr. PEREIRA, be observed:—A bitter, but peculiar taste; increased secretion of saliva; irritation in the throat; frequently nausea; disordered and laborious respiration, sometimes quick, at others slow and deep; pain in the head, giddiness, obscured vision, and sleepiness. In some instances faintness is experienced.

When administered in poisonous doses of moderate quantity, a remarkably bitter taste is experienced immediately after swallowing the acid; this is soon followed by a sensation of faintness and giddiness, with salivation, and is succeeded by tetanic convulsions and insensibility; the respiration is difficult and spasmodic; the odor of the acid may be recognized in the breath; the pupils are usually dilated, though sometimes contracted; the pulse is small and imperceptible. When recovery takes place it is usually very rapid, and the whole period of suffering seldom exceeds half an hour, though there have been exceptions, in which the symptoms have extended over several hours.

When hydrocyanic acid is taken into the human stomach in immoderate quantity, death supervenes so

speedily that the symptoms have scarcely been observed. They are probably similar to those noticed in animals, *vide hoc*, imperceptible pulse, breathing not obvious; or there may be two or three deep, hurried inspirations, insensibility, and death. Convulsions may or may not be present.

The great variation in the strength of the acid renders uncertain three points of inquiry, each in itself interesting; namely, the quantity required to produce death, the time at which it begins to operate, and the period at which it proves fatal. Peculiarities not known or understood also affect the result. Very strong acid, in large doses, begins to operate very speedily, especially if its vapor be inhaled. The diluted acid, on the other hand, sometimes does not produce any obvious effect for several minutes, and death may not occur for nearly half an hour.—*Pereira*.

The mode in which hydrocyanic acid acts on the human frame is not without interest. Dr. CHRISTISON cites the case of ROBIQUET, whose fingers were benumbed several days in consequence of their being exposed to the vapor of the acid. Hence it appears that the acid acts locally on the nerves. From the odor of the acid being exhaled from animals poisoned by it, and from the detection of it by KRAMER in the blood, it is clear that the poison is absorbed; but physiologists differ as to whether the remote effects produced by it are due to absorption. Dr. PEREIRA sums up the arguments which have been adduced in favor of this theory, as follow:—

Firstly: The acid produces no remote effects when applied either to the nerves or brain. Secondly: When applied to the tongue or stomach, it acts as an energetic poison, although the nerves of these parts were previously divided. Thirdly: That if the acid be applied to a part where circulation is arrested, the operation of the poison is prevented. Fourthly: The activity of the acid is in proportion to the absorbing powers of the part with which it is placed in contact. Fifthly: A sufficient time always elapses between its application to the body and the first symptom of its action, to admit of its operation by absorption.

The principal antidotes in cases of poisoning by hydrocyanic acid are chlorine, ammonia, cold affusion, and respiration by artificial means. Though the latter should on no account be omitted, yet the first two are universally admitted to be the most efficacious. Chlorine is given in various forms, as in very dilute aqueous solution, or which one, or two teaspoonfuls may be administered at intervals. Or a weak solution of chloroxide of calcium—bleaching powder—or of chloroxide of sodium may be substituted for chlorine water. Chlorine gas largely diluted with common air may be carefully inspired by the patient. Ammonia is employed in the ordinary fluid state, largely emasculated; but much has been said in favor of the inhalation of the vapor of ammonia or its carbonate, as the preferable way of employing the volatile alkali.

ADULTERATION.—It cannot be positively affirmed that hydrocyanic acid is intentionally adulterated, though there is considerable reason to believe that it is often sold in too dilute a state. But, amongst all the methods for its preparation, there are none by

which it can be prepared absolutely pure without the use of the utmost precautions in every stage of the process. Hence, when due care is wanting, deteriorating substances often find their way from the retort to the receiver in considerable quantity. Again, however careful may have been its production, it is liable to decomposition if not properly preserved; this is especially the case when, from recklessness in its preparation, it contains foreign principles; for these, by their action on one another, on the acid itself, or from spontaneous decomposition, may give rise to a multiplicity of products, till ultimately the acid has completely disappeared, and there remains instead an *olla podrida* worthless to the owner, and which, if administered as a remedial agent, might be productive of the worst consequences.

Pure hydrocyanic acid is entirely volatilized by heat. Should a residue be left when it is carefully evaporated, it may consist of bitartrate of potassa, oxide of lead, cyanide of mercury, or of other substances according to the mode by which it is produced. Thus, the acid made by CLARKE's method often contains a portion of the first-named salt; while that prepared according to the directions of VAUQUELIN may be contaminated with the latter substances.

The stronger acids, as sulphuric or hydrochloric, are frequently present. In this case, litmus paper is strongly and permanently reddened; and when a mixture of cyanide of mercury with iodide of potassium—formed by commingling the concentrated solutions of these salts, when the double compound falls in white crystalline plates—is added to the suspected acid, the beautiful red iodide of mercury is deposited. This test occasions no change if the hydrocyanic acid be pure.

Sulphuric acid may be detected by the addition of chloride of barium, which occasions a white precipitate, insoluble in nitric or hydrochloric acid.

Nitrate of silver causes a precipitate of cyanide of silver; and should hydrochloric acid be present, of chloride of silver. The former—cyanide—is dissolved on the addition of boiling concentrated nitric acid, while the latter remains as a white curdy deposit.

Hydrocyanic acid containing ammonia soon acquires a brown color. When treated with a strong solution of potassa in the cold, ammonia is evolved, and may be recognized by the smell, and by the white vapors which are observable when a glass stirrer moistened with hydrochloric acid is placed in immediate contiguity with it.

The acid prepared by VAUQUELIN's process frequently contains lead. This may be detected by passing a stream of sulphide of hydrogen through the acid; if lead is present in large quantity, a brownish-black deposit is speedily formed; when the amount is small, a brownish coloration only is occasioned. Sulphuric acid will likewise throw down a white precipitate of sulphate of lead.

VAUQUELIN's acid may also hold cyanide of mercury in solution, if the current of sulphide of hydrogen were not long enough continued in its preparation. It is detected by saturating the acid with this gas, when the brown sulphide of mercury is formed.

When the hydrocyanic acid has been prepared, by

distilling a metallic cyanide with sulphuric or hydrochloric acid, formic acid may be retained in solution. This acid reddens litmus more strongly and permanently than does the pure hydrocyanic acid. On dissolving suboxide of mercury in the acid, and heating the menstruum, the mercury is reduced, producing a grey cloudiness, from which, when deposited, globules of metallic mercury may be elicited by friction. According to GEIGER, if the greater part of the fluid be gently evaporated, the residue reduces suboxide of mercury with effervescence.

Should hydrosulphocyanic acid be present in hydrocyanic acid, it may immediately be discovered, by adding a salt of sesquioxide of iron, when a fine blood-red color, more or less deep, appears.

DETECTION AND DETERMINATION.—The detection of hydrocyanic acid is oftentimes of the greatest importance, especially in cases of poisoning. Of late years, chemistry has, in this respect, given evidence most important and incontrovertible.

In many instances, hydrocyanic acid may be recognized by its odor, even when in a dilute state, when surrounded by decaying organic matter, or when itself partially decomposed. According to ORFILA, this test is the most delicate one, since, he says, it gives very marked indications when those afforded by the liquid reagents are only slight. This statement, however, must be received carefully, as much is necessarily dependent on the nature of the mixture containing or supposed to contain the acid.

The reaction of caustic potassa, proto- and sesquioxide of iron, and hydrochloric acid, upon a fluid containing hydrocyanic acid, is a valuable means of detecting the latter. The mixture under examination is saturated with caustic potassa, and a solution of a proto- and sesquisalt of iron is added. The precipitate thus formed may vary in color, according to the quantity of potassa or of the salts of iron present; sometimes being yellowish, at others blue, and again, partaking of both hues, being green. Whatever be the tint, it is immediately changed to that of Prussian blue, on the addition of a little hydrochloric acid. Care must be taken not to employ too much potassa, which would prevent the development of the Prussian blue.

Nitrate of silver also indicates with great delicacy the presence of hydrocyanic acid, causing a white flocculent precipitate, soluble in boiling concentrated nitric acid. The latter property distinguishes it from the chloride of silver, which it much resembles. Should further proof be required that the deposited compound is the cyanide, it may be carefully dried, introduced into a glass tube, and heated in the flame of a spirit lamp. Cyanogen gas is evolved, and this is readily combustible, burning with a purplish flame.

The discovery of LIEBIG, that when hydrocyanic acid was mixed with sulphide of ammonium, and subjected to a moderate degree of heat, a compound—sulphocyanide of ammonium—was formed, which possessed the property of giving an intense blood-red color with the sesquisalts of iron, afforded a test for hydrocyanic acid, which is equal, if not superior, to any at present known. Dr. PEREIRA remarks:—When the acid is in small quantity, and mixed with solids or

fluids, partially decomposed, then a modification of this test will enable one to detect a quantity of the poison which, from its minuteness, and from the absence of the usual odor, might otherwise escape notice. This slightly varied method is as follows:—Introduce the poisoned liquid or solid into a beaker or other similar vessel, which it should fill to within half an inch of the brim. Place upon a large watch-glass, which fits with tolerable accuracy to the beaker, two or three drops of sulphide of ammonium, containing an excess of sulphur, and invert it over the liquid. In three or four minutes, the watch-glass may be removed, and the moistened spot dried, with care and very gently, over a spirit-lamp or sand-bath. A white film remains, which may be either sulphur—resulting from the evaporation of the sulphide of ammonium—or sulphocyanide of ammonium, formed by the action of hydrocyanic acid, in the suspected liquid, upon the sulphide of the volatile alkali. In the latter case, the film will have a crystalline character, which, if not visible to the unassisted eye, may be detected by means of a microscope. Further, the film, if of sulphur merely, is not affected when moistened with water, and treated with a drop of sesquichloride of iron; whereas, when it consists of sulphocyanide of ammonium, the ferruginous sesquisalt immediately occasions a blood-red color, which is discharged upon the addition of a few drops of a solution of chloride of mercury. Should the film upon the watch-glass have a yellowish color, it is probably sulphide of ammonium, in which case the iron salt will give a black precipitate of sulphide of iron, thus showing that the evaporation has not been sufficient.

It should be observed, that both the Prussian blue and the nitrate of silver tests should be applied, when the suspected substance, as in cases of poisoning, contains foreign matters upon a distillate. Thus, if the contents of a stomach are under examination, they are introduced into a tubulated retort, and one-half distilled by means of a vapor or water-bath. Should the substance be alkaline—soon known by applying red litmus paper, which is at once colored blue—it may be owing to the generation of ammonia by putrefactive decomposition, and it is advisable to introduce a few drops of sulphuric acid into the retort along with the matters to be distilled.

It has been suggested that hydrocyanic acid may be formed during the distillation of organic matters. Dr. CHRISTISON rightly remarks that this objection appears only to rest on conjecture or presumption. The Editor would advise in all cases of importance, that the sulphur test, as modified by Dr. PEREIRA, and given above, should be first resorted to, and then the other tests may be proceeded with upon the original substance or a distillate from it, as its nature may render advisable, without risk of error.

The determination of hydrocyanic acid, which now presents itself to notice, is often of considerable importance, but never more so than when it is required to know the strength of an acid for medicinal purposes. Formerly, the density and the strength of the acid were supposed to be proportional, and Dr. URE constructed a table of specific gravities and corresponding strengths; but it has since appeared that these are

fallacious. He subsequently proposed the following method:—Weigh out a portion of the hydrocyanic acid, and add, by degrees, a known quantity of red oxide of mercury, agitating the menstruum after each addition, till it is no longer dissolved, and the odor of the acid has disappeared. By weighing the remaining oxide, the quantity employed is known, and since one hundred and eight parts of oxide require twenty-seven of anhydrous hydrocyanic acid for its liquefaction, the proportion of the latter is readily calculated. But DUFLOS has shown that the cyanide of mercury first formed is capable of taking up more oxide, even at ordinary temperatures, so that this method gives too much acid, especially if the liquid is not kept quite cool, and the addition of oxide stopped as soon as the odor of hydrocyanic acid has disappeared. Care, too, must be taken that the acid is perfectly free from hydrochloric acid, which also dissolves the protoxide of mercury. In this case, GEOGHEGAN neutralizes the hydrochloric acid with carbonate of lime before adding the oxide.

The last-mentioned chemist has directed, for the estimation of prussic acid, that nitrate of silver mixed with a small quantity of ammonia—so that the liquid after precipitation may be rather acid than alkaline—should be dropped into a known quantity of the acid, as long as a precipitate is produced. This is collected on a previously dried and tared filter, welledulcorated, dried at 212°, and weighed. One hundred and thirty-five parts of cyanide of mercury represent twenty-seven of the anhydrous acid.

Perhaps the most elegant mode of determining hydrocyanic acid is that last suggested by LIENIG, and based upon the property of cyanide of potassium of dissolving chloride of silver, so as to produce a double cyanide containing an equivalent each of the cyanides of silver and potassium. The hydrocyanic acid is supersaturated with potassa, and mixed with a few drops of a solution of chloride of sodium; nitrate of silver is then added, until a permanent precipitate is produced. The proportion of the silver in the dissolved nitrate being known, the amount of hydrocyanic acid is readily calculated, since it is in the exact proportion of two equivalents to one of the silver consumed: thus supposing eighty-five grains of nitrate to have been used, which are equivalent to fifty-four of the metal, half the latter number—twenty-seven—will be the number of grains of anhydrous hydrocyanic acid present in the weighed portion operated upon. This nice method is also applicable for the estimation of the acid in cherry-laurel water, *et cetera*.

INK.—*Encre*, French; *Tinte*, German; *Atramentum*, Latin.—Ink, according to the purposes for which it is intended, is found in different forms. Writing ink, which is of various colors, is liquid, and may be either a clear fluid, as ordinary red ink, or may consist of a finely-divided precipitate equally diffused through the menstruum, as in common black ink. Printing ink is likewise of divers hues, but has a pasty consistence. The form of ink known as *Indian*, which is employed more especially as a water-color, is in solid cakes.

The present subject will be treated of in the following order:—

1. **Writing inks**, which are either *colored*, as black, red, blue, green, and violet; or *sympathetic*—that is, those which are colorless when committed to paper, as also when dried, but, by the application of heat, moisture, or of some compound which may be said to act as a mordant, they become visible, and are then either permanent or fugitive; in the latter case, the tint being generally caused to reappear by again applying the suitable means.

Besides these may be noticed the lithographic *transfer* inks, some kinds of which are used with the pen, and must consequently be included under this first class.

2. **Printing Inks.**—These, in all their numerous diversities of color and consistence, will be considered with reference to the purposes to which they are applied, as for letterpress, lithographic, and copperplate printing.

WRITING INKS.—There are few chemical preparations, perhaps none, of which the benefit in civilized life is so great, or of which the use is so widely extended, as that of common writing ink; consequently, there is no compound the quality of which it is so necessary to inquire into; and yet there is perhaps no subject which, up to a comparatively recent period, has been more neglected by chemists.

Before LEWIS, towards the close of the last century, directed his attention to the subject, no author appears to have particularly applied himself to inquire into the theory of the composition of ink, or to bring it to perfection. All that is to be found in the works of previous writers, consists merely of formulæ for various kinds of ink, which, being composed without any attention to chemical laws, were more or less defective; so that it may be truly said, that until the time of LEWIS, the preparation of writing fluids, the properties of which it is so essential to attend to, was left entirely to chance, or to empirical prescriptions.

It is indeed true, that some good kinds of ink have been discovered by accident; but those who devised them kept their composition secret, so that the public were either obliged to purchase those inks from the inventors, or to make use of such as were inferior in quality, and more or less perishable.

Ordinary black writing ink is now made from galls, sulphate of iron, green copperas, and gum. Other substances may be and often are employed, but those just named are the only requisite, and the best materials.

The ancient inks, according to the opinions of most writers, were similar to the Indian or Chinese ink of the present day. PLINY and VITRUVIUS allude to it as a combination of soot or lamp-black, with glue or gum; DIOSCORIDES even mentions the proportions of three of the former to one of the latter. To these, according to some authors, the liquor extracted from the cuttle-fish was added. When this could not be obtained, or from other causes, it is evident that some of the modern sulphurized ingredients were added by the ancients; many Greek and Roman manuscripts erased by the monks having been found to retain as much of the vitriolic principle as to become again legible on the application of chemical tests.—*Encyclopædia Britannica*.

Still, very little really definite knowledge of ancient writing inks can be obtained, and the Editor will therefore confine his attention to the modern ones.

Dr. LEWIS, already mentioned, found that equal weights of galls and sulphate of iron gave an ink, which, although of a good color when used, subsequently became yellowish-brown; that as the quantity of sulphate was increased, the inks were less durable in color, and that those in which the galls predominated, were most persistent. The proportions which he deemed best were:—

Powdered sulphate of iron,.....	1 ounce.
Ground logwood,.....	1 "
Bruised galls,.....	3 "
Gum-arabic,.....	1 "
White wine, or acetic acid,.....	1 quart.

He found that, although water answered for all ordinary purposes, white wine gave a deeper-colored product, and the ink made with acetic acid was still blacker. Alcohol was injurious to the hue, causing a deposition of the tinctorial precipitate. A decoction of logwood, substituted for water, improved the black both in richness and depth of tint. He directs the materials to be put into a glass, earthenware, or other non-metallic vessel, and the mixture agitated four or five times every day. In ten or twelve days it is ready for use—if placed in a warm situation, considerably earlier; but if the ink is allowed to remain on the matériel, it continues to improve for a lengthened period. When decanted, it may be kept in good order with greater certainty, if a few broken—not bruised—galls, and two or three fragments of iron, are placed in it.

LEWIS preferred distilled or rain water in making ink, but spring water containing calcareous salts is better adapted for the purpose. Some remarks on this subject, extracted from NAPIER, have been inserted in the article DYEING.—See Vol. I., page 584.

RIBAUCCOURT, who devoted much attention to the manufacture of inks, and published an extended paper in the *Annales de Chimie*, in the year 1798, observes:—None of the ingredients of ink should be in excess. If there be a deficiency of galls, a portion of the sulphate of iron will not be decomposed; if, on the contrary, the galls are in excess, the ferrous sulphate will take as much as it can decompose, but the remainder will be nearly in the state of decoction of galls, subject to change by becoming mouldy, or undergoing a transmutation after the ink has been used, destroying the legibility of the writing much more completely than would be the case were the sulphate of iron present in too large quantity. He further considers it doubtful whether the principles of galls are extracted by mere maceration, and says that inks thus made always flow pale from the pen, and are never of so deep a black as those in the manufacture of which the galls have been subjected to a long-continued boiling. The following recipe was devised by RIBAUCCOURT, as affording a good writing fluid:—

Boil eight ounces of coarsely-pulverized Aleppo galls and four ounces of thin logwood chips in twelve pounds of water for one hour, or until half the liquid is evaporated. Pass the decoction through a hair-sieve or

linen cloth, and then add four ounces of sulphate of iron, three ounces of gum-arabic, one ounce of sulphate of copper, and one ounce of sugar-candy. Agitate the mixture till the whole is dissolved, and leave it at rest for twenty-four hours; then decant the ink, and preserve it in well-stopped stoneware or glass bottles.

In making good writing ink, remarks Professor BRANDE, the great object is to regulate the proportion of sulphate of iron to the galls. If the former be in excess, although the ink may at first appear black, it becomes subsequently brown and yellow. Hence, some time should elapse before ink is used, after the ingredients are put together, in order to be tested from time to time, and the combinations perfectly regulated. The gum is added to retain the coloring matter in suspension, to prevent too great fluidity in the writing, and to protect the organic matter from decomposition.

If the paper has been made from inferior rags, bleached by an excess of chlorine, ink deposited upon it, however good, will be ultimately discolored. An excellent product is obtained as follows:—

Boil six ounces of finely-bruised Aleppo galls in six pints of water; then add four ounces of clean and well crystallized sulphate of iron, and four ounces of gum-arabic. Keep the whole in a wooden or glass vessel, occasionally shaken. In two months, strain, and pour off the ink into glass bottles.—*Brande*.

Dr. URE directs that twelve pounds of bruised galls be put into a cylindrical copper, of a depth equal to its diameter, and boiled, during three hours, with nine gallons of water, taking care to replace at intervals what may be dissipated by evaporation. The decoction is then to be emptied into a tub, allowed to settle, and the superstratum of liquid having been drawn off, the marc is to be drained. Some recommend the addition of a little bullock's blood or white of egg, to remove a portion of the tannin; but this abstraction, says URE, tends to lessen the product, and will seldom be practised by the manufacturer intent upon a large return for his capital. Five pounds of gum-senegal are next dissolved in a small quantity of hot water, and the mucilage thus formed, being filtered, is added to the clear decoction. Five pounds of sulphate of iron are now dissolved in as small a quantity of water as possible, and added. The color darkens by degrees, in consequence of the oxidation of the iron, on exposing the ink to the action of the air; when a moderately deep tint has been obtained, it should be drawn off clear into bottles, and well corked up. Dr. URE prefers digesting, rather than boiling, the galls.

The following prescription is given in the seventh volume of the *Pharmaceutical Journal*:—

Galls, bruised,.....	2 pounds.
Sulphate of iron,.....	5 "
Gum-arabic,.....	4 "
Water,.....	12 gallons.
Creosote,.....	2 drachms.

Boil the galls in three-fourths of the water for an hour, then strain. Liquefy the gum in twice its weight of hot water, and add it to the decoction. Dissolve the copperas in the remainder of the water, mix the liquors together, and finally stir in the creosote. It is very evident that in this recipe there is a great deficiency of

galls; otherwise, the quantity of sulphate of iron should be considerably reduced. The creosote is added as a preventive of mould, for which it is most efficient. BOOTH gives the following formulæ:—For superior black ink, take twelve pounds Aleppo galls, four pounds sulphate of iron, three and a half pounds of gum, and eighteen gallons of water. For a fine exchequer ink, forty pounds of Aleppo galls, nine pounds of sulphate of iron, ten pounds of gum, and forty-five gallons of water. In both these cases, it is directed that the bruised galls be exhausted by three consecutive boilings, each time diminishing the quantity of water, and supplying, by fresh addition, any loss by evaporation. The copperas and gum in solution are added to the strained decoction of galls, whilst both are yet warm, and the whole is allowed to repose for several weeks, when the fluid is drawn off from the sediment. A few cloves, or some drops of creosote are added, to prevent any parasitic growth.

REID gave, in the *Philosophical Transactions* of 1827, among many valuable observations which will subsequently be noticed in this article, the following proportions:—

Galls, bruised,	1 pound.
Sulphate of iron,	3 ounces, 64 grains.
Gum,	3 ounces, 64 grains.
Water,	3 quarts.

The galls are to be boiled with three pints of water till a quart of decoction remains; it is then poured off, the remainder of the water added, and ebullition continued until again a quart only is left. The two menstrua are then mixed, and the other ingredients dissolved in them; the whole is allowed to rest for twenty-four hours, when the fluid ink is poured off, and retained for use.

By another method, REID makes the decoction of galls as above directed, and exposes it freely to the air for ten days, agitating it two or three times each day. By this means much of the tannin is converted into gallic acid. To each quart of the decoction, add three and a half pints of water, nine ounces of sulphate of iron, and the same quantity of gum. The deposit which forms may, after three days, be separated, when the ink is fit for use.

Again, one pound of galls is exhausted as first directed, and the tannin of the decoction changed, by exposure, into gallic acid, as in the last instance. The menstruum is then mixed with a saturated solution of logwood, freshly made by boiling a pound and a half of the chips in five quarts of water, till the quantity is reduced to seven pints; eighteen ounces of sulphate of iron, and as many of gum, are dissolved in this mixed liquid; the whole is allowed to stand for two or three days, and the ink is then decanted from the sediment.

An attempt was formerly made to prepare ink by macerating iron filings in an infusion of galls; but though the resulting liquid was of the required hue, the writing produced with it was totally devoid of permanency, and was readily washed from the paper.

Japan ink is made as other inks, but the sulphate of iron is oxidised by roasting. This ink is intensely black when written with, but the color does not retain its depth or lustre. Besides these disadvantages, it

clogs the pen, and is, altogether, far from being worthy of recommendation.

Before giving the formulæ for, or notices of, inks prepared from other than the ordinary ingredients, it may be well to introduce here some remarks from a paper presented by Dr. BOSTOCK, in the year 1830, to the Society of Arts, which, though containing perhaps a few slight inaccuracies, is indicative of no small amount of research; and embodying, as it does to a great extent, the Editor's views, he does not consider any apology for its length to be requisite. Dr. BOSTOCK says:—

When the sulphate of iron and the infusion of galls are mixed, for the purpose of forming ink, it may be presumed that the metallic oxide enters into combination with at least four proximate vegetal principles, which constitute the bulk of the soluble portion of galls, namely, gallic and tannic acids, mucilage, and extractive matter. Two of these, the gallic acid and tannin, are more especially necessary to the constitution of ink, which is considered by some of the best chemists to be essentially a tanno-gallate of iron. It is also laid down, that the sesquioxide of iron alone possesses the property of forming the compound which constitutes black ink, and that the substance of the latter is mechanically suspended, rather than dissolved in it.

Ink, as it is usually prepared, is disposed to undergo certain changes, which considerably impair its value; of these the three following are the most important:—its tendency to moulding; the liability of the black matter to separate from the fluid, the ink then becoming what is termed *ropy*; and its loss of color, the black first changing to brown, and at length almost entirely disappearing.

Besides these, there are objects of minor importance to be attended to in the formation of ink. Its consistence should be such that it will easily flow from the pen, without being so fluid as to blur the paper, or so adhesive as to clog the pen, and to be long in drying. The shade of color is not to be disregarded; a black, approaching to blue, is generally preferred to a browner ink; and a degree of lustre or glossiness, if compatible with the due spissitude of the fluid, tends to render the characters more legible and beautiful.

With respect to the chemical constitution of ink, Dr. BOSTOCK remarks that although, as usually prepared, it is a combination of the metallic salt or oxide with tannic and gallic acids, mucilage, and extractive matter; yet the last three of them, so far from being essential, are, without doubt, the principal cause of the difficulty which is encountered in the formation of a perfect and durable ink. He illustrated this point by a series of experiments. Having prepared an infusion of galls, a portion of it was exposed to the atmosphere in a shallow capsule, until it was covered with a thick stratum of mould; this being removed by filtration, and the proper proportion of sulphate of iron added to the clear fluid, a compound was formed of a deep black hue, which showed no further tendency to foul, and which remained for a long time without undergoing any further alteration.

Another portion of the same infusion of galls had a

solution of isinglass added to it, until a precipitate was no longer occasioned; by adding sulphate of iron to the filtered liquid, a black compound was produced, which, although paler than that made from the entire fluid, appeared to be a perfect and durable ink.

Lastly, a portion of the infusion of galls was subjected to continued ebullition, by which means part of its contents became insoluble; the menstruum was filtered, and sulphate of iron added to the filtrate, producing a good and permanent ink.

Dr. BOSTOCK presumes that the three causes of deterioration in writing fluids, the fungoid growth, the subsidence of the black compound, and the loss of color, are dependent upon the operation of different proximate principles: the first change he ascribes to the mucilage; the second to the extractive matter, from the property which it possesses of forming insoluble compounds with metallic oxides; the third he believes to be owing to the tannic acid, which probably, in the first instance, forms a triple compound with the gallic acid and the iron, and that, in consequence of the decomposition of the tannin, this body is subsequently destroyed. Owing to the difficulty, if not impossibility of depriving the infusion of galls of any one of its ingredients, without, in some degree, affecting the others, the last-named authority was unable to obtain any results which could be considered decisive; but experiments led him to conclude that, in proportion as ink consists merely of the gallate of iron, it is less liable to decomposition, or to experience any kind of metamorphosis.

Dr. BOSTOCK's summary is as follows:—In order to procure an ink which may be little disposed either to mould or to deposit its contents, and which, at the same time, may possess a deep black hue not liable to fade, the galls should be macerated for some hours in hot water, and the fluid filtered; the filtrate should be then exposed for about fourteen days to a warm atmosphere, when any fungoid growth that may be observed must be removed. A solution of sulphate of iron is to be employed which has been boiled, or exposed for some time to the air, and in which there is consequently an admixture of sesquioxide of iron. If the infusion of galls be made considerably stronger than is generally directed, the ink formed in this manner will not necessarily require the addition of a mucilaginous substance to render it of a proper consistence.

Dr. BOSTOCK adds further, in the *Transactions of the Society of Arts*, that one of the best fluids for diluting ink, if it be, in the first instance, too thick for use, or if it afterwards become so by evaporation, is a strong decoction of coffee, which does not appear to occasion the decomposition of the ink, while it improves its hue, and gives it an additional lustre.

The black color produced by galls in union with sulphate of iron, although faulty from its disposition to precipitate and decompose, was, from its being the only known method of making a black tinctorial solution, the sole article used during a very considerable period for atramental purposes. To those whose chief employment consisted in writing, copying, &c. *cetera*, the least defect in the ink caused a more or less serious addition to their labor, and the improvements made in

this fluid may, therefore, be considered as real and valuable benefits.

A semi-colored solution, such as were the old ferro-gallic inks, requiring the addition of gum to prevent the deposition of the tinctorial matter, was especially liable to thicken, and flow tardily from the pen: this in sultry weather, when evaporation is rapid, became especially irksome. The introduction of the steel pen made these imperfections more manifest, causing a greater liability in the ink to concrete and deposit its coloring matter.

Writing inks were in this state when the improvements introduced by Mr. HENRY STEPHENS of London first appeared. This gentleman, applying the knowledge of chemistry which he obtained in his studies for the medical profession, to which he once belonged, engaged in extensive and successful researches upon atramental fluids.

The first improvement introduced by him consisted of a blue liquid, which had the startling novelty of becoming intensely black in a few hours after its deposition on the paper. It had the great recommendation of perfect fluidity, and the ease with which it was transferred from pen to paper, coupled with its ready but tenacious combination with the latter, were, at that time, considered really remarkable. This now celebrated writing fluid is a tanno-gallate of iron dissolved in sulphate of indigo; the common ferro-gallic writing inks consist of a liquid in which the tinctorial matter is suspended by means of gum, while in this the color is in complete solution.

RUNGE, after endeavoring for a long time to find a black fluid possessing the properties of forming no deposit, of adhering strongly to the paper, of being unaffected by acids, and, lastly, of neither acting nor being acted upon by steel pens, succeeded after many experiments. The composition has the advantages of being very simple and exceedingly cheap. It is prepared by adding one part of chromate of potassa to one thousand parts of a saturated solution of logwood, made by boiling twenty-two pounds of logwood in a sufficient quantity of water to give fourteen gallons of decoction; to this menstruum, when cold, the chromate is gradually added, and the mixture well stirred. The addition of gum is injurious. In the preparation of this ink, it must be remembered that the chromate, not the bichromate, of potassa is employed, and great care is requisite to insure the due adjustment of the relative proportions of the ingredients used. The best way is to make the decoction of logwood, and gradually add to it, well stirring the mixture, as much solution of chromate as will give the desired shade.

It appears astonishing, says RUNGE, what a small quantity of chromate of potassa is required to convert a large amount of decoction of logwood into a black writing fluid; the fact is, however, certain, and care must be taken not to allow the proportion of chrome salt to exceed one part for one thousand parts of decoction of logwood, as a larger quantity exercises a prejudicial effect in destroying the tinctorial matter of the liquid, whilst, in the proportion above mentioned, a deep blue-black writing ink is formed, which, unlike the ink made with tanno-gallate of iron, is perfectly fluid, forming no deposit. This fluid possesses another advantage; the paper which has been written upon

with it may be washed with a sponge, or be left twenty-four hours under water, without the marks being erased. Weak acids do not destroy the writing, nor do they even change the shade, whilst that made from galls is effaced, and the ink made with logwood and sulphate of iron is turned red.

It is especially necessary, in using this atramental fluid, that the steel pens should be well cleansed from the greasy matter with which, when new, they are always coated. This may either be done in the usual way, by moistening them with saliva, and subsequently washing them with water; or, preferably, by applying to them an alkaline solution. RUNGE used this ink for two years without his steel pens being in the least affected, either by being crusted, or clogged with solid matter, or by becoming rusty.

Professor TRAILL has proposed a formula for ink as follows:—Gluten, obtained in the ordinary way, is kept from twenty-four to thirty-six hours in water, and is then digested in acetic acid having the specific gravity 1.033 or 1.034, in the proportion of three parts of gluten to twenty parts of the acid. By the aid of a gentle heat, a greyish-white, saponaceous fluid, which may be kept for some time, is obtained. From eight to twelve grains of the finest lamp-black, and two grains of indigo, form the coloring matter for each fluid ounce of the vehicle, with which it must be thoroughly incorporated. An agreeable aroma may be communicated by digesting bruised cloves, pimento, or cinnamon, in a portion of the original acid. This ink may be used with a steel pen, but should not be left in it, and the pen should be washed after use; it is not calculated for writing on parchment.—*Edinburgh Philosophical Transactions*.

Mr. HENRY STEPHENS has invented an indelible carbon ink, which, if at all equalled, is certainly not surpassed. His process is as follows:—

Take common carbonated alkali, or the potassa or soda of commerce, or ammonia, or some other alkaline compound, and mix it with resinous matter,—as shell-lac or common resin,—in about equal proportions; then add water according to the required strength of the solution, and boil the whole until the resinous substance, or the greater portion of it, has dissolved; next mix the necessary quantity of fine lamp-black with this solution. A black liquid will thus be produced, which may be mixed with other suitable colored solutions, to form an indelible ink. Such tinctorial matter as is soluble in alkali, will best assimilate with this composition.

A recipe for an indelible carbon ink, published in the year 1845, by HERBERGEN, is perfectly identical with that of Dr. TRAILL just given.

Dr. NORMANDY has suggested an indelible writing ink, which cannot be obliterated or defaced by any known chemical agent. Twenty-four pounds of Frankfort black must be ground with mucilage—formed by adding twenty pounds of gum to sixty gallons of water—and the mixture strained through a coarse flannel, or passed through a funnel the tube of which is closed by a sponge; four pounds of oxalic acid are then added, together with as much decoction of cochineal and sulphate of indigo as will give the required shade.

Many substitutes for galls, in the manufacture of ink, have been suggested—principally for the sake of economy. Those of Dr. NORMANDY and M. GIROND are most worthy of notice. The former chemist employs sumach, elm wood, elder, chestnut, beech, willow, oak, plum, sycamore, cherry, poplar wood, catechu, or any other ligneous matter or berry, or extract of vegetal substances, containing gallic acid and tannin, or either of these principles. In making ink by this method, which is patented, the bark, wood, or berry, as the case may be, is reduced to powder, and boiled with water until a sufficiently strong decoction has been obtained. The quantity of water must vary, of course, according to the sort of vegetal substance employed; thus sumach will demand more water than catechu, on account of the latter being almost wholly soluble. To the menstruum is added a certain amount of logwood, of acetate and hydrate of protoxide of copper, of sulphate of alumina and potassa, and of sulphate of protoxide of iron, in quantities which must be regulated according to the nature of the organic matter first made use of. Gum-arabic or a superior quality of gum-senegal is now added, in the proportion of eighty pounds or thereabouts for each three hundred and forty gallons of liquid; also a variable amount of sulphate. As the quantity of the ingredients must be regulated by the shade of the tint intended to be produced, it is impossible to indicate absolutely the proportions in which they are to be employed; this must be decided by the taste and fancy of the manipulator. Supposing, however, that a blue-black is desired, and that sumach is the vegetal substance to which preference is given, the annexed are the proportions for two hundred and forty gallons of the ink:—Sumach, from forty-eight to sixty bushels; logwood, about two hundredweight—the quantity slightly varying, according as new or old chip is taken; gum-arabic, from eighty to one hundred and twelve pounds; protosulphate of iron, one hundredweight; acetate and hydrate of protoxide of copper, four pounds; sulphate of alumina and potassa, thirty-seven pounds; sulphate of indigo, six pounds or more, according to the required intensity of the blue. Were catechu to be employed in this case, instead of sumach, one hundredweight would be required, the proportions of the other materials remaining the same.

The obstacles which have hitherto prevented the use of the above-named astringent vegetal substances instead of galls, are the variously-colored precipitates which they afford with salts of iron, some being quite green, others brown, while decoction of galls yields with sulphate of iron a dark purple. These hues may, however, be altered at will, by the use of sulphate of indigo in different proportions, from dark-blue to the most intense black, applicable to dyeing, staining, or writing, and which may be employed with every description of pen.

The substitute for galls, patented by GIROND in 1825, is denominated by him, *lanajavag*, and consists of an extract from the shell, wood, or sap of the chestnut tree.

One hundredweight of chestnut shells, broken into fragments, is to be immersed in from one hundred and

eighty to two hundred gallons of water, in a vessel of copper or other material *except iron*; and after having been allowed to soak for about twelve hours, heat is applied, and ebullition maintained for about twelve hours. If the wood of the chestnut tree is employed, it is cut into small pieces or thin shavings, and treated in the same way.

The extract is drawn off from the boiler at the end of the time specified, and filtered through a fine sieve or cloth, after which the water is evaporated from it until it becomes of a pasty consistence, when it may be cut into cakes of any convenient size, and dried in an oven at a low temperature till hard, at which time it is ready for use.

In making ink with this substitute, it is merely necessary to reduce it to a coarse powder, and use it as galls.

One hundredweight of chestnut shells yields eight or ten pounds of the dry extract.

SCOTT, in the year 1840, patented the following method for the manufacture of ink:—

Take forty-eight pounds of logwood chips, and let them be saturated two days in soft water; then boil them in a closely-covered iron caldron, with eighty gallons of the last-named liquid, for one hour and a half, when the wood must be taken out, and forty-eight pounds of the best Aleppo galls added to the menstruum, which must be boiled for half an hour, and subsequently allowed to remain in the vessel for twenty-four hours, during which time it must be frequently agitated. When the principles of the galls have been sufficiently extracted, draw off the clear fluid into a vat, and add forty pounds of pulverized sulphate of iron; let these ingredients remain for a week, during which time they should be daily agitated; then pour in four gallons of vinegar. Next take seven and a half pounds of the best picked gum-arabic, and dissolve it in sufficient water to form a good mucilage, which must be well strained, and then by degrees be mixed with the fluid; let these stand a few days longer, then add twenty ounces of concentrated nitrate of iron. When the menstruum has attained a sufficient depth of color, it is carefully decanted from the sediment, and the following substances, each separately prepared and ground, added to it:—

First, grind half a pound of Spanish indigo by means of a muller and stone, till it is very fine, occasionally adding portions of the ink until it is made into an easily soluble paste; then take five pounds of well-washed and purified Prussian blue, which must be prepared as the indigo, except that distilled water must be employed instead of the partially-prepared writing fluid. Next take four ounces of *gas-black*,—that is, the carbon collected from the smoke of gas-burners on glass surfaces—and grind it with one ounce of the nitrate of iron. These several substances are allowed to remain for a few hours unmixed, when the whole may be incorporated with the fluid, which is daily agitated for a week. The clear ink, in quantity about eighty gallons, is then poured off for use.

The Rev. J. B. READE of Aylesbury took out patents in the year 1847 for various writing, marking, and printing inks. The first only will be here noticed; the second and third will be described in their proper

places in the subsequent part of the article. The only black writing ink which he has devised, is made by mixing soluble Prussian blue of a good quality—prepared by Mr. READE's own patent, and described in the manufacture of his blue ink—with ordinary gall ink. This addition of Prussian blue makes the ink, which was already unaffected by alkalies, equally proof against acids, and a writing fluid is thus obtained which cannot, according to the patentee, be erased from paper by any common method of obliteration without destroying the tissue.

Two or three black inks now remain to be noticed, which, from the nature of the ingredients, can hardly be classed with the common varieties, and have, on that account, been reserved for description to the last. The first, and not the least important, of these is BENZELIUS' indelible ink, prepared from the metal vanadium. Vanadic acid, when combined with ammonia, thus forming a vanadate of the volatile alkali, and mixed with an infusion of galls, forms a black fluid, which, according to the inventor, is the best writing ink that can be used. The quantity of salt necessary for a perfectly black ink is so small, that, to use the great chemist's own expression, it will not be worth considering when vanadium is more generally known. The writing obtained with this ink is perfectly black. Acids do not obliterate it, though they cause the color to become blue. Alkalies, when diluted so as not to act upon the paper, do not dissolve it. Chlorine, though it destroys the black color, does not efface the writing, even when water is suffered to run over it. Though this ink cannot be said to be absolutely indelible, yet it strongly resists reagents which cause common ink to disappear. It has also the advantage of being a solution, and not merely a precipitate suspended in a fluid by means of gum, so that it flows more freely from the pen.

COATHURNE has given a formula for an ink capable of resisting the action of all the substances usually employed for effacing writing. It is prepared as follows:—Boil, in a loosely-covered tin vessel, two ounces of shell-lac and one ounce of borax with eighteen ounces of distilled or rain water, stirring them occasionally until the whole is perfectly homogeneous; filter the mixture, when cold, through bibulous paper, and mix the filtrate—in quantity about nineteen ounces—with one ounce of mucilage of gum-arabic, made by dissolving the gum in double its weight of water, and add pulverized indigo and lamp-black *ad libitum*. Seethe the whole again in a covered vessel, and agitate the menstruum thoroughly in order to effect the complete solution of the gum and the admixture of the coloring matters. This agitation is continued during the cooling of the fluid, after which it is allowed to repose for a few hours, so as to permit the deposition of the excess of indigo and carbon, when it is decanted and bottled for use.

An *indelible safety ink*, patented by WHITFIELD in 1837, is prepared in the following manner:—Four gallons of linseed oil; two of cocoa-nut oil; one gallon of good molasses; five pounds of loaf sugar; two pounds each of ground sacre seed, ground cotton seed, Venice turpentine, ivory black, Antwerp black, finely-powdered

burnt horns, tartar, pulverized gum-kino, and anacardium nuts; four pounds each of very finely-powdered charcoal, dried bullocks' blood, and gum-arabic; one pound each of solution of caoutchouc, parchment-shavings, powdered seed-lac, and Indian borax; and three pounds each of Aleppo galls, pomegranate peel, fine glue, and walnut skins, all in fine powder,—are mixed and boiled in a large iron caldron. On the commencement of ebullition, the mixture is ignited with a bar of red-hot iron, and the smoke which is liberated is received into a capacious inverted cone made of the best sheet-iron. As soon as the whole of the oil is consumed, the carbon which adheres to the cone is collected and carefully preserved. The residuum is then removed from the boiler, and rubbed down on a stone slab to an impalpable powder. One pound of the carbon collected in the cone, and a similar quantity of the prepared residuum, are then mixed with a quart of the best French vinegar, two gallons of hot water, and four ounces of gum-lac, and these ingredients are then boiled for ten minutes, when one pound of Aleppo galls in fine powder, and two pounds of logwood chips are added. The mixture is stirred until cold, and is then poured into large flat pans, and exposed to the atmosphere for three weeks.

Whatever may be the qualities of this ink when manufactured, it is certainly prepared in a singular manner. A mere tyro in chemical science will at once perceive that the materials are selected and proportioned so as to form a rare *olla podrida*, while the subsequent treatment of them is, to say the very least of it, wasteful in the extreme.

Copying inks, or inks which, after having been transferred from pen to paper, and having become dry, will communicate a portion of their substance to a sheet of damped paper strongly compressed upon them, thus furnishing two, and, in some instances—by renewed application, with pressure, of clean moistened paper—even a third or fourth copy of the same manuscript, are generally prepared by adding a modicum of sugar or sugar-candy, with an increased amount of gum, to the ordinary ferro-gallic inks.

RED INK.—The red inks at present in common use are of two kinds, of which, however, there are some modifications.

The first variety is prepared by making a solution of the tinctorial matter of Brazil-wood in acetic acid, the color being raised by means of alum.

BOOTH gives the following formula for a red ink:—Brazil-wood, two ounces; chloride of tin, half a drachm; gum-arabic, one drachm; water, thirty-two ounces. These ingredients are subjected to continuous ebullition, until the quantity of fluid amounts to only sixteen ounces.

HEULEN's recipe is here given:—Boil two ounces of Brazil-wood, half an ounce of pulverized alum, and the same quantity of crystals of bitartrate of potassa in sixteen ounces of distilled water, until the fluid is reduced to one-half. Strain the liquor, dissolve in it half an ounce of gum-arabic, then mix with it a tincture made by digesting a drachm and a half of cochineal in one and a half ounce of alcohol of specific gravity 0.839.

Red inks of the second class are prepared from cochineal or carmin; the most common modification is a simple solution of the latter in an excess of ammonia, the proportions being varied according to the depth of color required. Such ink is extremely fugitive.

The following recipe is given in the *Pharmaceutical Journal*:—Place in a porcelain vessel twelve grains of pure carmin, and pour thereon three ounces of solution of ammonia; heat over a spirit-lamp for a space of from five to eight minutes, carefully regulating the temperature so that ebullition shall not occur, and to the solution thus formed, add, continually stirring, eighteen grains of powdered gum-arabic. When this is liquefied, the ink is ready for use. Drop lake may be substituted for the carmin, as being more economical.

According to OHME, a good red ink may be made by macerating, for two days, six drachms of powdered cochineal, and one ounce and a half of pure carbonate of potassa, with sixteen ounces of water. Four and a half ounces of bitartrate of potassa and three drachms of alum are then to be added, and the fluid heated as long as carbonic acid is evolved. After the liquid has been filtered, the contents of the filter are to be washed in one ounce and a half of water, and one ounce of alcohol is then added to the resulting fluid, as an antiseptic. For most purposes, six drachms of gum-arabic should be dissolved in each sixteen ounces of this ink; but when used as a tinctorial agent in confectionery, for which it is well fitted, the addition of gum is unnecessary.

Mr. STEPHENS obtains an excellent red ink from cochineal by the following method:—Add to a quantity of common carbonate of potassa, soda, or ammonia, twice its weight of crude argol in powder. When the effervescence caused by the combination of the tartaric acid of the argol with the alkaline base, thereby expelling the carbonic acid, has ceased, decant or filter the solution from the insoluble matter; to this is added, by measure, half its quantity of oxalate of alumina, prepared by dissolving damp, newly-precipitated alumina in as small a quantity as possible of a concentrated solution of oxalic acid. The mixture thus prepared is next colored, when cold, with bruised or powdered cochineal, and after standing for forty-eight hours is strained, when it is fit for use.

The Rev. J. B. READE took out a patent for a red ink in the year 1847. Subjoined is his mode of preparing it:—Cochineal is first boiled in successive quantities of pure water, till it ceases, or nearly so, to afford tinctorial matter. It is then subjected to ebullition with dilute ammonia, which dissolves the remainder of the tint-giving principle, leaving the animal matter nearly white. These aqueous and ammoniacal decoctions are then mixed in an earthenware vessel, and the coloring matter is then thrown down by means of the double chloride of ammonium and tin. The compound thus formed is subsequently boiled in ammonia, and iodide of tin is then added, till the required degree of brilliancy of hue is obtained; this completes the process, the degree of body required in the ink being given by an *ad libitum* addition of water. This ink, says the patentee, is greatly superior to the com-

mon solutions from peach and Brazil-wood, not only in permanent richness of color, but also in its freedom from acid, and consequent fitness for use with steel pens.

BLUE INK.—There appears to have been no true ink of a persistent blue color, until Mr. STEPHENS introduced his *unchangeable blue writing fluid*.

Reflecting upon the durable nature of Prussian blue, as well as upon its beautiful and strong contrast to white paper, Mr. STEPHENS was led into an investigation of the means of dissolving it, so as to adapt it to atramentation, while, at the same time, it might be made serviceable to the dyer; and oxalic acid was found to answer the purpose. The ink is prepared as follows:—Take Prussian blue—whether it is that of commerce, or purposely prepared by a combination of a sesquisalt of iron with ferrocyanide of potassium, is immaterial—put it into an earthen vessel, and pour upon it as much strong acid as will cover it. Hydrochloric, nitric, and sulphuric acids are equally of service; but if the latter be used, it should be diluted with a quantity of water equal to its own bulk. The Prussian blue is allowed to remain in the acid from twenty-four to forty-eight hours, or even for a more extended period; the mixture is then diluted with much water, at the same time agitating it, for the purpose of washing from it the salts of iron. When in this state of dilution, it is permitted to rest until all the color has subsided, at which time the supernatant liquid is siphoned off, and a further quantity of water added. This process is repeated until ferrocyanide of potassium no longer evinces the presence of iron by giving a blue precipitate; and also until the menstruum ceases to redden blue litmus paper, thus proving that the acid has been entirely removed. The product is then placed upon a filter, and suffered to remain until all the liquid has drained away. The Prussian blue, by this treatment, has lost a considerable proportion of its iron, and is now more readily acted upon and dissolved than in any other condition. After being gently dried, oxalic acid is added to, and carefully mixed with, the Prussian blue; cold distilled water is then poured, in small portions at a time, over the whole, making it into a dense or dilute solution, according to the depth of color required. The amount of oxalic acid may be varied according to the quantity of water used. It will be found that Prussian blue which has undergone the process of digestion just described, requires but a small modicum of acid to dissolve it. For a concentrated solution, six parts of Prussian blue—weighed before the treatment with acid—will, after the operation, be taken up by one part of oxalic acid, and a proportional amount of water. Prussian blue, in its ordinary state, will require two or three times its weight of oxalic acid; and even then, it will be liable to precipitation after standing; when deprived of a portion of its iron in the first place, by means of acid, it remains a permanent solution.

The comparative durability of the ordinary black ferrogallic ink and that made from the sesquiferrocyanide of iron—Prussian blue—may be judged of by the following:—

Black ink is a combination of a protosalt of iron

with the active principles of galls; the tannogallate of iron thus produced is good whilst the metal remains as protoxide; but, as soon as the salt has passed into a higher state of oxidation, the ink has a tendency to decay; and as still more oxygen is attracted and combined, the vegetal matter is decomposed, until eventually there remains on the paper only oxide of iron of a reddish-brown hue, similar to that produced when the ink is acted upon by chlorine. If the writing is kept from the air, and all damp is excluded, the color of the ink will be unaffected for many years; but should the manuscript be placed in a damp position, the iron soon passes into the state of sesquioxide, and the vegetal portion of the ink becomes extinct.

The ink from Prussian blue has a reversed principle as regards its permanence. While the iron is in its normal degree of oxidation, the color is only partially developed, and it is not until the iron is further oxidised by means of an acid, or by exposure to the atmosphere, that the fine deep hue is fully developed. It is here that the uniform well-known tendency of the lower oxides of iron to absorb oxygen, instead of being an evil, is of positive service. As the state of sesquioxide is the true condition in which iron combines with ferrocyanogen to give Prussian blue, and as the inherent disposition of the iron is to assume this form, it is clear that the tendency of the elements is to be permanent. As a further proof of this, if writing executed with Prussian blue ink be exposed for a longer or shorter period to the action of strong light, a deoxidation of the iron occurs, and the color is to all appearance faded; but, on removing it from the influence of light, the iron reassumes the state of sesquioxide, and the color again becomes dark: this change may be repeatedly effected in the same manuscript, with an unvarying result. This repeated deoxidation by light, and the reverse action from want of solar or other rays, is generally known and well exemplified in the case of articles of external dress dyed with Prussian blue, which, being worn—and consequently exposed to the influence of strong light, not the less powerful because coming from its primary source, the sun—become pale, and lose that brilliancy for which Prussian blue, as a tinctorial substance, is so celebrated; but when these habiliments are again brought out, after being exposed for some time to darkness, the color is revived as by magic, and is again equal to new.

On adding a solution of ferrocyanide of potassium to ordinary black ink, a blue hue results; the affinity of the iron for the ferrocyanogen being so much stronger than that which it has for the tannic and gallic acids, the latter are displaced, thereby showing the greater force of combination in the blue, over that in the black ink. Many acids are destructive of the color of the latter, but the sesquiferrocyanide of iron is unaffected by any. Even chlorine has no action upon it, except that it perhaps deepens the shade a little. Of excess of moisture and light, and of the thousand and one physical causes which operate destructively upon black ink, only one affects the preparation of Prussian blue—light, and the action of this, as has been seen, is far from being permanent.

The Rev. J. B. READE has also patented a blue ink, which is manufactured as under :—

A solution of iodide of iron having been carefully prepared according to the usual method, a proportion of iodine amounting to half the weight already employed, is dissolved therein, and the mixture is then poured into a semi-saturated solution of ferrocyanide of potassium, employing of this salt a quantity about equal to that of the whole of the iodine used in the first-mentioned menstruum. A decomposition of the materials thus brought together immediately takes place, the ferrocyanogen of the potassium salt combining with the iron, and falling down in a solid form; while the potassium and iodine unite to form an iodide of the alkali-metal, which remains in solution, together with a slight excess of iodide of iron. The whole is placed on a filter; the retained deposit, caused by the union of the iron with the ferrocyanogen, and which is nothing more or less than Prussian blue in a soluble state, is well washed with, and is finally dissolved in water, which forms the blue ink desired.

Dr. NORMANDY has proposed a blue ink, which is made by operating upon Chinese blue, or ferrocyanide of iron. Three drachms of the ferrocyanide are macerated in seven ounces of water, with one drachm of binoxalate of potassa, adding one drachm of gum-arabic. A solution of tin may be added to these ingredients; the binoxalate of potassa may also be substituted by an equivalent proportion of oxalic acid.

OHME recommends the following formula for blue ink :—Dissolve one scruple of iron in nitrohydrochloric acid—aqua regia—filter the solution, and dilute it with sufficient water to make eight ounces, which is mixed with four drachms of ferrocyanide of potassium, previously dissolved in eight ounces of water. The resulting subsidence is collected on a filter, and after the fluid has, as far as possible, been removed, the precipitate is edulcorated with pure water, until the latter passes through, having an azure tint. As soon as this occurs, the funnel and its contents are placed over a clean vessel, the filter pierced, and the blue compound washed with twenty-four ounces, by weight, of water. This latter menstruum constitutes the blue ink, the formation of which depends on the property of the precipitate to dissolve in pure water, and not in solutions of other salts.

PURPLE INK.—To produce a purple-colored ink, called the *King of Purples*, Dr. NORMANDY recommends the following method :—To twelve pounds of Campeachy logwood, add as many gallons of boiling water; pour the infusion through a funnel with a strainer made of coarse flannel, on one pound of hydrate or acetate of copper—verdigris—finely powdered; at the bottom of the funnel a sponge is placed; then add immediately fourteen pounds of alum, and for each seventeen gallons of liquid, add four pounds of gum-arabic or senegal; let these remain for three or four days, and a beautiful purple will be produced.

GREEN INK.—KLAPROTH directs for the preparation of green ink, that two parts of acetate of copper and one of bitartrate of potassa be boiled in eight parts of water, till the solution be reduced to half the bulk. It is then filtered through cloth, and after cooling, bottled.

WINCKLER has given the following recipe for a green ink :—Dissolve one hundred and eighty grains of bichromate of potassa in one fluid ounce of water; add to the menstruum, while warm, half an ounce of spirit of wine; then decompose the mixture with concentrated sulphuric acid until it assumes a brown color. The liquor is now evaporated till it is reduced in quantity to one-half, when it is diluted with two ounces of distilled water, filtered, mixed with half an ounce of alcohol, subsequently with a few drops of strong sulphuric acid, and then allowed to rest till, after some time, it assumes a beautiful green color. It is finally adapted for use by the addition of a small quantity of gum-arabic.

OHME has devised a green ink, made by triturating one drachm of gamboge with one ounce of the blue ink invented by him, and previously noticed; but it is of little value.

YELLOW INK.—Yellow ink, according to Dr. URE, is prepared by dissolving three parts of alum in one hundred parts of water, adding twenty-five parts of bruised Persian or Avignon berries, boiling the mixture for an hour, filtering the liquor, and dissolving in it four parts of gum-arabic.

An extemporaneous yellow ink may be made by dissolving gamboge in water, but it is by no means permanent.

GOLD AND SILVER INKS.—Gold ink is prepared as follows :—Grind upon a porphyry slab with a muller, gold leaf and fine white honey, till the former is reduced to an impalpable powder. The paste is then carefully collected and diffused through water, which dissolves the honey, causing the deposition of the precious metal; the water must now be decanted, and the sediment edulcorated to free it from the saccharine matter. The powder exsiccated is very brilliant, and when required for use is suspended in mucilage of gum-arabic. After the writing executed with this ink is dry, it should be burnished with ivory.

Silver ink is prepared in the same manner, by substituting this metal, in leaf, for the gold.—*Ure*.

INDIAN OR CHINESE INK consists essentially of lamp-black formed into cakes by means of some glutinous or adhesive substance, such as gum-water. The lamp-black is said to be made in China by collecting the smoke of the oil of sesamé; and M. MERIMÉ states that the Chinese do not use glue in the fabrication of their ink, but certain vegetable juices, which render it more brilliant and more indelible upon paper. Dr. URE remarks, that when the best lamp-black is levigated with the purest gelatin or solution of glue, it forms, no doubt, an ink of a good color, but wants the shining fracture, and is not so permanent on paper as good China ink. In the latter has been detected about two per cent. of camphor, which is supposed to improve it. On the other hand, PROUST says that lamp-black, purified by potash lie, when mixed with a solution of refined glue, and dried, formed an ink which was preferred by artists to that of China. A good Indian ink may be made with ivory black, ground to a fine powder, made into a paste with weak gum-arabic water, and then formed into cakes.

MARKING INK.—The fluids for writing on linen now known are widely different from those in vogue even

a few years ago. The latter always required a preparation of the tissue, previous to their application. The formulæ for a few of these are given, not so much on account of the likelihood of their being again useful, as to give an insight into their composition, thereby showing what science has accomplished even in such a limited sphere.

Marking inks are of two kinds: the first of these is applied with the pen, the second with types.

One of the older marking inks, in using which the linen required to be *pounced* or prepared, is as under:—Dissolve one hundred grains of nitrate of silver, two drachms of gum-arabic, and one scruple of sap green in one ounce of distilled water. The linen is to be wetted before applying this, with a pounce, consisting of a solution of one ounce of carbonate of soda in eight of distilled water.

GRAY directs that the ink be composed of two drachms of nitrate of silver, six drachms of water, and two of mucilage, while one ounce of carbonate of soda in sixteen of water, together with a little sap green, form the pounce. Another ink is a solution of one drachm of nitrate of silver, one of mucilage, in five drachms of distilled water, tinged slightly by means of sap green. The pounce consists of, carbonate of soda, one ounce; gum-arabic, one ounce; water, six ounces.

A form of ink known as Italian is merely terchloride of gold, the cloth being moistened before its application with a solution of chloride of tin.

The modern marking inks do not require the pouncing of the linen previous to its being written upon; but instead, a hot iron is passed over the marks, or the cloth is held near the fire, till the color has been properly developed.

REDWOOD gives the following as the requisite properties of marking ink:—

1. That it shall flow freely from the pen, and form a well-defined mark, without running or blotting.
2. That it shall not require the application of a very strong or long-continued heat, by holding the article that has been written on to the fire, or by passing a hot iron over it, to develop the required hue.
3. That the marks produced by it, when brought out by heat or by exposure to light, shall be perfectly black.
4. That it shall not injure the texture of the finest cambric.

Subjoined is a very common formula for this kind of ink:—

Six drachms of nitrate of silver are dissolved in three ounces of distilled water, and as much ammonia is added as will liquefy the precipitate which it at first occasions. A little sap-green, ivory-black, Indian ink or indigo, diffused through four drachms of mucilage of gum-arabic, form the temporary tinctorial matter, and water is added to make up the quantity to four ounces.

Many marking inks, although black when first applied to the linen, become gradually washed out, and a yellowish stain only remains. JULES GUILLER has given three recipes for marking ink, which he believes to be free from these and some other prevalent evils. They are as under:—

For the first ink, twenty-two parts of carbonate of

soda are dissolved in eighty-five of distilled water, and twenty parts of pulverized gum-arabic are diffused through the menstruum. Eleven parts of nitrate of silver are then liquefied in twenty parts of ammonia, and this is commingled with the alkaline solution. The mixed fluids are next warmed in a flask, by which they become greyish-black, and partly coagulated; subsequently, brown and clear; then, when ebullition commences, very dark, and of such a consistence that it will flow readily from the pen. This ink, and that prepared from the next formula, have the advantages that no precipitates are formed in them, and that they insipitate by boiling, whereby their color becomes darker. For the second ink take,—

	Parts.
Nitrate of silver,.....	5
Distilled water,.....	12
Powdered gum-arabic, ..	5
Carbonate of soda,.....	7
Ammonia,.....	10

Treat these ingredients in the manner last described, and heat the resulting mixture in a flask until it has acquired a very dark tint, which is generally the case when its volume has diminished, by evaporation, about five per cent. By continuing the evaporation too long, a precipitate is occasioned in consequence of the loss of volatile alkali. The ink prepared in this manner is distinguished by producing very black characters upon linen, and is very suitable for marking with stamps or stencil-plates.

According to the third prescription, twenty-two parts of carbonate of soda are dissolved in twenty-five of distilled water; as also seventeen parts of nitrate of silver in forty-two parts of ammonia. Twenty parts of gum are then liquefied in sixty parts of water, and mixed with the soda solution, and afterwards with that of nitrate of silver, and lastly, thirty-three parts of sulphate of copper are added.

The large quantity of ammonia in this ink, says GUILLER, is accounted for by the presence of the cupreous salt. The latter might be replaced by nitrate of silver, but a much larger amount of this would be required to render the ink as dark as it is with the sulphate of copper. Whilst other marking inks have a dark-brown color, this ink possesses a rich blue. The proportions of the ingredients in these inks can be altered according to the consistency required, the uses to which they are to be applied, or the description and quality of the textile fabric on which they will be deposited.

REDWOOD's ink, which answers all the conditions—given above—that a marking ink ought to possess, is prepared in the following manner:—

Dissolve one ounce of nitrate of silver, and one and a half of crystallized carbonate of soda in separate portions of distilled water, and mix the solutions; collect the resulting precipitate on a filter, edulcorate it well with distilled water, and introduce it, while still moist, into a Wedgwood-ware mortar; add eight scruples of tartaric acid, and triturate the whole until effervescence has ceased: next add a sufficient quantity of ammonia to dissolve the tartrate of silver; mix in four fluid drachms of archil, four drachms of white sugar, and twelve of finely-powdered gum-arabic; and pour

in as much distilled water as will make six ounces of mixture.

The essential distinction between this and ordinary inks is the use of tartrate instead of nitrate of silver.

Long after REDWOOD had published his formula, generously laying his invention open for public use, the Rev. J. B. READE devised and patented two inks, the principle of which was identical with that of REDWOOD. Happening to meet with an ink made according to REDWOOD's recipe, he threatened the manufacturer with legal proceedings; but was prevented doing so by REDWOOD's showing with whom the invention originated. As other compounds are implied in Mr. READE's inks, the formula for each is appended:—

The first of these, which may be used with steel pens, and which is most readily developed on the application of heat, is prepared in the subjoined manner:—Nitrate of silver is triturated in a mortar with an equivalent of desiccated tartaric acid. Water is then added, which causes the separation of crystals of tartrate of silver, nitric acid being set free. The latter is neutralized carefully by adding ammonia, which also dissolves the metallic tartrate. Gum, tinctorial matter, and water are subsequently added in quantities which may be varied at pleasure.

By this process, remarks the patentee, the nitric acid, which is essential to a good marking ink, is retained, and the tartrate of silver formed is soluble in half the quantity of ammonia ordinarily required when nitrate of silver is the basis of the ink.

The second of the inks under this patent is made as follows:—

To a portion of ink formed by the process last described, is added an ammoniacal solution of an oxide, or salt of gold. The patentee has employed for this purpose the purple of Cassius—formed by precipitating a solution of the tetrachloride or other salt of gold by means of a tin salt—sulphide of gold, the iodide of gold and ammonia, and also the teriodide of gold and ammonia. The last two compounds, which Mr. READE considers to be *new*, he obtains by dissolving iodine in ammonia with application of heat; this operation must be conducted with great caution, in order to prevent the formation of that explosive compound, teriodide of nitrogen. The iodine solution thus obtained is a valuable solvent for gold. If this metal, in leaf, be placed upon it without the addition of water, a black deposition of gold is formed, which immediately dissolves; but, if the menstruum be diluted, the oxidation proceeds less rapidly, and the gold leaf assumes before solution, not a black, but a fine purple color. This salt of gold crystallizes in four-sided prisms, soluble in water. A few drops of this solution placed on a slip of glass, generally form arborescent, microscopic crystals, from which, by application of heat, the iodine and ammonia are volatilized, and arborescent metallic gold alone remains. If the heat be applied but moderately, only one equivalent of iodine is dispelled, and white crystals of iodide of ammonium and gold are left.

A purple-red marking ink consists of a solution of one drachm of bichloride of platinum in two ounces of distilled water. Before writing with it, prepare the

linen with a pounce made by liquefying three drachms of carbonate of soda and three drachms of gum-arabic in an ounce and a half of water.

SYMPATHETIC INK.—By sympathetic ink is meant a fluid which, being employed in writing, does not leave a trace of color upon the paper, but which, when exposed to moisture or heat, or when washed over with some vegetal or mineral solution, or subjected to some other agency according to its nature and chemical characteristics, becomes visible, the characters being then developed in a more or less apparent manner.

OVID mentions the method of writing with new milk, the characters being subsequently developed, even after the lapse of some time, by coal-dust or soot. The same means are proposed by AUSONIUS. It may be easily perceived that instead of milk, any other colorless and glutinous juice might be employed, as it would equally retain the black powder sprinkled upon it. PLINY, perceiving this, recommends the milky sap of certain plants.

Of all sympathetic inks, none, perhaps, is more remarkable than a solution of acetate of lead. The delineations made by this menstruum are rendered intensely black by means of sulphide of hydrogen—known also as hydrosulphuric acid, and as sulphuretted hydrogen—whether it be in a gaseous or liquid state. This effect, remarks BERGMANN, presented itself, perhaps accidentally, to some chemist; but the discovery is not of great antiquity. The first person who gave a receipt for preparing this ink, as far as the historian just quoted could learn, was PETER BOREL. In a work by him, printed in 1653, and again in 1657 at Paris, of which there were several subsequent editions, it is called a magnetic water which acts at a distance. In these days, phenomena, the causes of which were unknown, and particularly those which seemed to occur without any visible agency, were ascribed to *magnetic effluvia*. Others concealed their ignorance under what they called *sympathy*. The recipe for making these liquids, under the name of sympathetic ink, is first given by LE MORT, and that cognomen has not only been retained with reference to a solution of acetate of lead, but has also been applied to other fluids when employed for the same purposes.

Another and more beautiful sympathetic ink is that prepared from cobalt, the writing of which disappears in the cold, but appears again of a rich green color, as often as one chooses, after being exposed to a moderate degree of heat. This invention is generally ascribed, writes BERGMANN, to the French chemist HELLOT. He was, indeed, the first person who, after experimenting with it, made it public, but he was not the discoverer; he acknowledges that a German artist of Stolberg first showed him a reddish salt, which, when exposed to heat, became blue, and which, he assured him, was made out of Schneesberg cobalt with aqua regia—nitro-hydrochloric acid; but, if it be true that THEOPHRASTUS PARACELUS could represent a garden in winter by this invention, it must unquestionably be older.

The development of chemistry in modern times, and the consequent discovery of an immense number of chemical compounds, have given rise to an almost infinite

variety of sympathetic inks. Some of the principal ones will be described:—

Black.—write with a solution of acetate of lead, or ternitrate of bismuth, and wash the writing over with an aqueous solution of sulphide of hydrogen, which causes the formation of sulphide of lead in the first instance, and of tersulphide of bismuth in the latter case. Or chloride of mercury may be used as the ink, to be developed by being placed in contact with chloride of tin; metallic mercury, in a minute state of division, being thus thrown down. A sympathetic ink, identical with common black writing fluid, consists of a solution of sulphate of iron; tincture or decoction of galls being employed as the mordant.

Blue.—employ nitrate of cobalt as the ink, with oxalic acid as a mordant—in this case oxalate of cobalt is formed; or sulphate of iron may be used for writing, which is to be washed over with ferrocyanide of potassium.

Yellow.—use chloride of antimony as the ink, and moisten the writing with decoction of galls; or inscribe the characters with subacetate of lead, and develop them by means of hydriodic acid. A dilute solution of chloride of copper forms a beautiful sympathetic ink, which is invisible until gently heated, when the letters assume a fine yellow color, which disappears as the paper cools.

Green sympathetic ink consists simply of a solution of chloride of cobalt, with a small quantity of a salt of nickel. Writing done with the colorless arseniate of potassa, and washed over with nitrate of copper, becomes beautifully green.

Purple is produced by edulcorating, with chloride of tin, writing executed with chloride of gold, the *purple of Cassius* being in this case formed.

The substances which may be employed as sympathetic inks, either *per se* or in conjunction with others, are exceedingly numerous; but they are so generally known that it is needless to describe them.

LITHOGRAPHIC WRITING INK.—There are two kinds of ink used in lithography,—that which is employed by the lithographic writer in tracing an inscription or design on paper with a view to its subsequent transference to the stone; and that which is employed in taking impressions on paper from engraved plates with a view to the same object. The composition of the latter will be stated under Printing Inks. The writing ink is composed of ingredients mixed in the following proportions:—For one and a half ounce of shellac, take two ounces of soap, three ounces of white wax, and about one ounce of tallow; add about three table-spoonfuls of a strong solution of gum-sandarach, and when ready color with lamp-black.

PRINTING INKS.—*Encre d'imprimerie*, French; *Buchdruckerfarbe*, German.—Printing ink, though of greater importance than that used for writing, has not engaged the attention of scientific men to any extent, and few works have been published respecting it. No printers of the present day make their own ink, although many add ingredients which they believe to improve the color or quality. It is an especial business, and demands considerable capital. Every manufacturer has his own secrets, both as to material and process; and

by long experience alone can printing-ink makers so select and apportion the various ingredients as to adapt it to its numerous requirements.

The commonest book-ink costs eighteenpence per pound, while the usual qualities are from two shillings and sixpence to four shillings; black ink for superior work is worth five to six shillings, while for the finest carmine ink as much as thirty shillings per pound is paid. In the latter case, the value of the tinctorial matter enhances the cost; but, when the care and labor required in the preparation are taken into consideration, it is evident that it is not the mere value of the ingredients which fixes its price.

PROPERTIES.—Printing ink, as every one must be aware, is a very different composition from that used for writing. It is a soft, glossy compound, having a certain amount of adhesiveness, and becoming, by exposure in thin layers, perfectly hard and firm. Besides these properties, which always belong to it, it possesses other and varying attributes according to the numerous purposes to which it is applied. Its preparation demands not only a tolerable proportion of scientific knowledge, but also very careful manipulation; and manufacturers have found that, to produce it of good quality, both experience and deep study are requisite. The very important use for which it is designed—the registering in a permanent manner the productions of the mind—indicates some of the properties it ought to possess. The most valuable of these is durability, or the capacity to resist successfully the obliterating influence of time; and it ought, at the same time, to have brightness and depth of tint. It must be a mutable preparation, passing from the soft adhesive state to that of a perfectly hard and dry substance, and this change of condition must have a certain rate of progress, and be to some extent under control. When prepared, some time generally elapses before it is used, and during this period it ought not to alter in the slightest degree; in fact, when the air is excluded from it, it should keep for almost any length of time. During its application to the types, its solidification ought to be as slow as possible, and unaccompanied by the emission of any unpleasant or deleterious odor. It ought not to affect the soft, elastic rollers which are employed to convey it to the type or woodcut form, and which, unless the ink be a perfectly innocuous preparation, are liable to considerable injury. The change of state should not be accompanied by the deposition of consolidated matter in the ink, as this impedes the workman, and proves a loss to the printer.

The trying circumstances, as regards the quality of printing ink, do not end here. Having been applied, its action must be confined to a very slight penetration into the paper,—just sufficient to prevent its detachment without materially injuring the surface of the latter. It ought to dry up, in a very short space of time, to a hard, inodorous, unalterable solid.

Printing ink should, moreover, have an oleaginous character; it ought to be very glossy, and perfectly free from any granular appearance. If, on the extraction of a small portion from a mass, it leaves but a short thread suspended, it is considered good; but the best

test of its consistency is the adhesion it shows upon pressing the finger against a quantity of it.

MATERIALS.—The ingredients of ordinary printing ink are *burnt* linseed oil, resin, and occasionally soap, with various coloring matters. A slight notice of these is required.

Linseed Oil.—The best quality of oil is used, and this is purified by digesting it in partially-diluted sulphuric acid for some hours, at a temperature of about 212°, allowing the impurities to subside, and then washing away the acid with repeated additions of hot water. The oil after this treatment is pale and turbid, and, if the edulcoration is complete, there is scarcely any odor. By rest the oil clarifies, and has then a pale lemon color. It now dries much more rapidly than before. For an experiment, four drops of oil were exposed on a slip of glass: the first was ordinary Baltic linseed oil; the second was East India oil; the third and fourth were two distinct oils which had been purified by means of sulphuric acid. In the course of a fortnight, the first was colorless and rather viscid, but no skin or pellicle had formed on its surface; the second was colorless, but had no apparent viscosity; the third and fourth were not only colorless, but a tenacious film covered the surface of each.

The purified oil is now partially resinified by heat. For this purpose it is introduced into large cast-iron pots, and boiled until inflammable vapors are freely evolved. These are ignited, and allowed to burn for a few minutes, after which they are extinguished by placing a tight cover over the boiler. Ebullition of the oil is continued until, on cooling, a firm skin forms on its surface, known by placing a drop on a slate or other smooth cold material.

According to SAVAGE,—who has written at considerable length on this subject, and whose inks gained the large medal of the Society for the Encouragement of Arts,—the linseed oil cannot be brought, however long boiled, unless inflamed, into a proper state for making printing ink. Certain it is, that by the ebullition and ignition just noticed, the original character of the oil is totally altered; it is at first turbid, but clarifies when allowed to repose; it is now viscid and more or less adhesive; it penetrates paper with difficulty; it dries much faster than when unburnt; and it has now a pyrogenous and not unpleasant odor, which soon passes off from a thin layer exposed to the air. Fragments of slightly charred bread are by some added to the boiling oil, but no marked benefit arises from such a procedure.

Other drying oils besides linseed are occasionally used, but their cost or other considerations prevent their general adoption. Resin oil is indeed pretty largely employed by some makers; but, apart from other disadvantages, its disagreeable and permanent smell prevents its entering into other ink than that intended for temporary or common printing, as newspapers, placards, *et cetera*.

Resin is an article of considerable importance in the manufacture of printing ink, since, when dissolved in the oil—after the latter has undergone ebullition and inflammation—it communicates *body* to the fluid, and the compound bears a great resemblance to Canadian balsam. For many inks, the quality of the common

black resin is sufficiently good; but some require the pale, clear, transparent resin, obtained by remelting and clarifying the residue of the distillation of turpentine with water.

THE COLORING MATTERS of printing ink demand great attention, as much of the beauty of the typography depends upon them.

Black.—The universal ingredient for this color is lamp-black. There are vast buildings, as a writer in the *Encyclopedia Britannica* remarks, appropriated to the sole purpose of burning oil, naphtha, spirit, coal-gas, *et cetera*, to produce this black, which is collected from the sides and ceilings of the chambers. It is imported from Germany and many other countries, and no expense is spared to get the most superior quality.

Other black substances are occasionally employed. Charcoal from various sources, when reduced to an impalpable powder, and mixed with the other ingredients, furnishes a deep blue-black ink that dries rapidly. Carbonized vine-stalks, wine-lies, woods of various kinds—in fact, carbonized lignin from any source, when ground sufficiently fine—sometimes a tedious and costly operation—answer well; as also does bone-black. The brown tint possessed by lamp-black is not unfrequently neutralized by the addition of blue compounds, as indigo, Prussian blue, *et cetera*.

For red ink, carmin, lake, vermillion, red lead— Pb_3O_2 —Indian and Venetian red, are employed.

A blue color is supplied by Prussian blue, indigo, Antwerp blue, *et cetera*.

Chromate and bichromate of lead—known respectively as lemon and orange chrome, or as chrome yellow and chrome red—yellow ochre, gamboge, and other pigments, furnish a yellow hue.

Green is obtained by means of arseniate of copper, or by a union of blue and yellow colors.

For brown, burnt sienna, umber, sepia, and mixtures of red with black, are employed.

PREPARATION.—In the manufacture of printing ink, the resin is dissolved in the burnt oil, in cast-iron pots or boilers, and the varnish, thus prepared, is introduced into what is termed the *mixing vessel*, which is cylindrical, and in the centre of which, bars or rods of iron, attached to a perpendicular shaft, revolve in a horizontal position. The black or other coloring matter is then added to the hot varnish, and the whole, when thoroughly mixed, is drawn off through an opening in the base of the vessel. The *pulp* is next very carefully ground, by being passed between hard stones of a very fine texture, driven by heavy machinery, the motive power being steam. Sometimes a second grinding is requisite, but this may generally be avoided by taking care that the varnish of resin and oil is clear and free from gritty particles, and that the black is in an impalpable state.

The proportions and conditions of the various ingredients vary considerably, and great experience is required before an ink can be prepared to suit any one purpose. The oil has to be rendered more viscid, by burning, in some cases than in others; sometimes the quantity or kind of resin requires to be varied; or, perhaps, different proportions of color are requisite. Newspapers printed by steam-power require an ink of

less substance than that employed for book-work, which must be tolerably *stiff*. For woodcuts, the ink must not only be stiff, but very fine. The qualities of the material to which the ink is applied, furnish an additional guide in this matter: thin paper must have a soft ink, which *works clearly*, and is not too adhesive. A fine stout paper, on the other hand, will bear a stiffer and more glutinous ink; and as resin supplies these properties, so does it in a great measure communicate brilliancy, and the most perfect and splendid effects are by these means produced.

USE gives the following directions for making printing ink:—

To one and a half gallon of linseed oil, burnt and boiled, as above described, till a portion, extracted from the pot by means of a pallet-knife and cooled, draws out between the fingers into strings of about half an inch in length—add gradually six pounds of resin. When this has dissolved, twenty-eight ounces of dry brown soap of the best quality, cut into slices, are introduced cautiously, for the combined water causes a violent intumescence. Both the resin and soap are well stirred in, and the whole is then ignited for a few moments, in order to complete the admixture of the constituents. Two and a half ounces each of ground indigo and Prussian blue, together with four pounds of the best *mineral* lamp-black, and three and a half pounds of good *vegetal* lamp-black, are placed in an earthenware pan, sufficiently large to contain the whole of the ink, and the warm varnish is then added by degrees, carefully stirring, to produce complete incorporation of all the ingredients; and the mixture is, finally, ground into a smooth uniform paste.

The two succeeding recipes are from the *Encyclopædia Britannica*, the first being that used by BASKERVILLE and BULMER, and giving excellent results:—

1. Dissolve a small quantity of black or amber resin in three gallons of fine old linseed oil, which has been boiled to a thick varnish, and cooled in small quantities; allow the mixture to stand for some months, so that all impurities may subside, then mix with the best lamp-black, and grind carefully.

2. One hundred pounds of nut or linseed oil are reduced by boiling and burning to one-eighth its bulk, and to the consistence of a sirup; two pounds of coarse bread and several onions (!) being thrown in to purify it from grease. Thirty or thirty-five pounds of turpentine are boiled apart, until, when the residue is cooled on paper, it breaks clean, without pulverizing. The former is poured nearly cold into the latter, and well mixed. The compound is then boiled again, a sufficient quantity of lamp-black is incorporated, and when the ink is well ground, it is ready for use.

One pound of printing ink may be made by the subjoined recipe of SAVAGE:—

Balsam of copaiba, nine ounces; lamp-black, three ounces; indigo and Prussian blue, ground together in equal proportions, one and a quarter ounce; Indian red, three-fourths of an ounce; dry, yellow turpentine soap, three ounces: this mixture is to be ground, by means of a slab and muller, to an impalpable smoothness. It is stated that this ink possesses a beautiful color, but appears to work foul.

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JOHN BIRD took out a patent for substituting a mineral found in Merionethshire and other localities, instead of lamp-black. The mineral is freed from debris by washing, when it becomes a very black paste; and subsequently, on drying, a fine, black, impalpable powder, composed of—

	Centesimal.
Silicic acid,	46.00
Alumina,	42.00
Carbonaceous matter,	12.00
	100.00

The preparation of printing ink with this pigment is, in other respects, according to ordinary methods.

A patent was granted in 1854 to THOMAS DE LA RUE, by which glycerin is employed as a vehicle for making a fugitive ink, peculiarly applicable for the printing of bankers' cheques and other similar documents. For this purpose he precipitates logwood and vegetal substances, suitable for producing coloring matters, and grinds them up with glycerin to the consistency of ordinary printing ink.

The Rev. J. B. READ's patents for printing ink are as under:—

He describes two blue printing inks: the one is made by taking the soluble Prussian blue obtained in the manufacture of his blue writing ink, and rubbing it up with oil; or, by triturating with oil the residue obtained by evaporating his blue ink.

For the second blue ink, he prepares the soluble Prussian blue with bromine instead of iodine, and diffuse it in oil.

His first black printing ink is made in like manner from his black writing fluid.

A second black printing ink is made by boiling chips of logwood—for which an extract of logwood may be substituted—or other dyewoods containing coloring matter and tannin, with as much proto- or persalt of iron or of copper, as will be equal to about twice the weight of the tannin contained in the wood or extract employed; a black or bluish-black precipitate is thus obtained, the blueness of which is diminished, as required by the addition of a greater or less quantity of bichromate of potassa. The whole is finally triturated with oil; a little lamp-black, or other black coloring matter usually employed in the manufacture of printing inks, being added.

LITHOGRAPHIC PRINTING INK.—The composition of lithographic writing ink has been already given. That which is employed to take impressions on paper from engraved plates, with a view to their transference to the stone, may be composed as follows:—Tallow, wax, and soap, of each four ounces; shellac, three ounces; gum-mastic, two and a half ounces; black pitch, one ounce and a half; to which add lamp-black to color.

The Editor cannot conclude the present article without expressing his thanks to Mr. HENRY STEPHENS, for his kindness in supplying him with information respecting writing inks; and also to Messrs. BENJAMIN SMITH and Son—who make the ink with which this work is printed, and who have a world-wide fame for the excellence of their productions—for similar favors with regard to printing ink.

3 3

IODINE.—*Iode*, French; *Iod*, German; *Iodium*, Latin.—This body is one of those which chemists designate elements, from the circumstance, that by no means or agency at their disposal are they enabled to extract any other form of matter from it. It may be regarded as a new substance, being discovered by M. COURTOIS, manufacturer of saltpetre—nitrate of potassa—in Paris, in the year 1812–13; and of all the simple bodies which have attracted the attention of chemists, iodine seems to be the most interesting, as, since its isolation, it has never ceased to present wide fields of investigation to the chemist and physician; many of these have been diligently explored and cultivated, but still sufficient remain untrodden to keep alive that scientific interest with which iodine has been invested from the date of its discovery. It is well known that chemistry has extended her domain of research principally during the last forty years; but even anterior to that period, chemical knowledge was so far advanced that the discovery of iodine might have been expected to take place long before its announcement by COURTOIS. That this should not have been the case is the more surprising, when the wide range of its distribution is considered, and its presence, particularly in reagents which the chemists of 1800, and their predecessors, were in the habit of using and preparing in a state of comparative purity; moreover, its characteristic appearance in the form of vapor, its odor, and the remarkable reactions which it produces, render the circumstance of its having escaped observation the more striking. The discovery of iodine is interesting, inasmuch as it was not a result arrived at by unguided experiment, as in the case of many bodies which might be cited, but of patient research. The multiplied unsuccessful attempts of COURTOIS to isolate it would be tedious to relate; but some idea may be formed of his numerous experiments and failures, from the first observation he made relative to the destruction of his copper pans employed in the decomposition of nitrate of lime with the alkaline lie of the varec or kelp, till he succeeded in tracing the effect to the cause, and in preparing iodine in a very pure state from the mother waters of his various processes. This discovery was made, as already stated, in 1812, and was announced by M. CLEMENT DESORMES at the meeting of the Institute on the 29th November, 1813. At this period iodine was anxiously sought after and studied by the celebrities of the day. By degrees it came to be known that other substances besides the ashes of sea-plants contained it, and since then numerous researches have shown that iodine is one of the most widely-disseminated elements, although, it may be remarked, that its aggregate amount is comparatively small. In the mineral kingdom it is met with, combined with silver and mercury, in ores from Mexico; in Silesian galmei it is found combined with zinc; and it has been detected in species of lead ore from South America; it is contained as iodide of potassium or sodium in the nitrate of soda from Chili, and has been detected similarly combined in the rock-salt of Hall in the Tyrol. Many springs have been found to yield quantities of iodine, united, doubtless, with the alkali metals, potassium and sodium, and with mag-

nesium; of this description are the waters of Bex, Stülze in Mecklenburg, Rolberg in Pomerania, Salzuffeln in Königsbrunn, near Unna, Rehme, near Minden, Schönebeck, Halle in Saxony, Dürrenberg and Kösen, Artern and Salzgungen, Schonalkalden, Salzhausen and Kreuznach, Bolechow and Drochobycz in Galicia, Kenahwa in North America, Guaca in the province of Antioquia in New Granada. Its presence has likewise been proved in the following mineral waters; namely, in the thermal spring of Albano, in one near Sales in Piedmont, in several salt springs near Ascoli, in the hepatic waters of Castel Nuovo d'Asti, in the hot spring of Aix in Savoy, in the Bonnington water near Leith, in Bath water, in the water from Marienbad in Bohemia, and also in the waters from Carlsbad, Heilbrunn, and Kunzig in Bavaria; in the medicinal waters of Hall in Austria, used for the cure of goitre; in the hepatic water of Trutkawice, and in the alkaline waters of Iwonicez in Galicia. Besides these, later investigations have proved its presence in several other waters of every description. A vast amount of iodine exists in the ocean; but, from the minute centesimal proportion in which it is present, DAVY, GAULTIER, FYFE, and others, failed to detect it. In the plants which grow in the sea, as well as on its shores, the iodine is, so to speak, concentrated, and consequently, when the ashes of these are submitted to the usual tests for its detection, its presence is readily manifested. The following plants were found by SARPHATI to contain iodine in the quantities mentioned:—

	Ppt Cent
<i>Fucus filum</i> ,	0.0894
“ <i>digitatus</i> ,	0.1350
“ <i>saccharinus</i> ,	0.2300
“ <i>nodosus</i> ,	—
“ <i>vesiculosus</i> ,	0.001
“ <i>saccatus</i> ,	0.121
<i>Lotus siliculosus</i> ,	0.142

DAVY, GAULTIER, and FYFE found iodine in the following:—*Fucus cartilagineus*, *membranaceus*, *rubens*, and *palmatus*; according to SARPHATI, it is contained in *Sphærococcus crispus*; he found it also in *Ulva Linza*, *pavonia*, *umbellalis*; likewise in *Lactuca* and *Zostera marina*. *Lichen confinis*, *Statice armeria*, and *Grinnia maritima*, growing upon rocks on which sea-water has been blown by the wind, have yielded this element; but *Ramalina scopulorum*, growing in the same situation, gave no indication to DICKIE of the presence of iodine. *Pila marina* contains it; and it is obtained in large quantities from the ashes of various species of *Fucus*, *Ulva*, and other sea-plants, which constitute the varec of Bretagne, and the kelp of the Scotch and Irish. The ashes of several shore-plants, such as the different kinds of *salsola*, and such as are used for producing the barilla of Spain and the Sicilian soda, contain very little or no iodine.

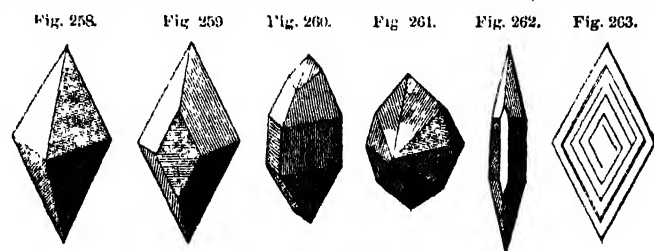
The marine animals which yield iodine are:—The Common sponge, the Horse sponge, *Lapis spongiarum*, *Spongia oculata*, *Flustra foliacea*, various species of *Sertularia* and *Tubularia*, various kinds of *Rhizostoma* and *Cyana*, *Asterias rubens*, *Crogon vulgaris*, *Mytilus edulis*; oysters contain it, and likewise various species of *Dorus* and *Venus*. It is found in cod-liver oil; and the oil from the liver of the *Raja clavata* and *Raja*

balis give indications of its presence; and from the statements of JONAS, it appears that traces of it are afforded by Scotch salt herrings. Besides these, many other substances of the animal and vegetable kingdom contain small traces of this element. Lately it has been detected in the ashes of various coals and shaly matters; and from the researches of M. CHATIN and others, it has transpired that rain water, dew, air, rose leaves, *et cetera*, give to properly-regulated experiments appreciable traces of iodine.

PROPERTIES.—M. GAY-LUSSAC was the first who investigated and discovered the general properties of this element, being succeeded by Sir HUMPHREY DAVY, VAUQUELIN, and several others. To prepare iodine, varec or kelp is exhausted with hot water, which dissolves about one half of this substance; the liquid is filtered and concentrated, and the chief part of the chloride of sodium, sulphate of soda, chloride of potassium, and other salts, is crystallized out, leaving a mother-liquor which, besides the iodide of sodium, retains other bodies in solution, such as sulphide of sodium, hyposulphate of soda, and traces of those already mentioned. This liquid is treated with sulphuric acid in a retort, when the more unstable compounds are decomposed, and sulphates of the bases produced; and on the application of a gentle heat, the iodine passes over into the condenser. In this state it is rarely pure, but is contaminated with chlorine, sulphur, and saline matters; it may be purified from these, however, by washing with water, filtering, and pressing between folds of bibulous paper, then subliming it a second time. A better method is to dissolve the iodine in alcohol, filter from any residue, and precipitate with water. The deposit collected and dried in the usual way, is pure iodine.

So prepared, it presents a bluish black appearance, and a metallic lustre very similar to that of black-lead or specular iron ore. It is generally obtained in crystals, which are modifications of an elongated octahedron with a rhomboidal base, the primary form be-

evaporation in very small quantity, but which is increased when the air is loaded with moisture. When in a thin stratum, the vapor of iodine presents a beautiful rich violet shade from which its name is derived; but if examined in layers a few inches thick, it no longer presents this appearance, but rather a black mass, impervious to diffused day or candle light. Vapor of iodine is the heaviest of all known gases, being, according to the investigations of DUMAS, of specific gravity 8.717, and by calculation from its atomic weight, 8.7077. Alcohol and ether dissolve it in all proportions, producing dark reddish-brown liquids; water takes up only one seven-thousandth of its weight of this element. The solvent action is increased, however, when there are other salts dissolved in the liquid, such as nitrates or chlorides. In either case a brownish liquid is formed, which, by long exposure, disappears, the iodine being transformed into iodic and hydriodic acids. It is capable of uniting with most of the non-metallic elements, producing with some—such as nitrogen—highly explosive compounds; and with others—oxygen and hydrogen—acids which are capable of neutralizing bases, and thus forming salts, many of which are very important. The mineral acids, chlorine and several other bodies, are capable of displacing and reducing these compounds of iodine, and of setting the latter free when it colors the liquid brownish-red. A characteristic and remarkable property of iodine discovered by MM. COLIN and GAULTIER DE CLAUVRAY, is the blue coloration it affords when brought in contact with starch-paste disseminated in water. This is so delicate and characteristic, that it still remains the test for iodine in all investigations, affording, according to STROMMEYER, a perceptibly blue tinge when not more than one four hundred and fifty-thousandth part of iodine is contained in the liquid. KERSTING has latterly discovered that, by the use of a palladium salt, so small a quantity as the millionth part of iodine may be detected in a liquid. This subject will be referred to further on. The starch test should be applied with some caution, however, as a large excess of the amylaceous substance causes the blue coloration to vanish. Heat also destroys it; and hence, in testing for iodine, the liquids must be cold. This reaction is not produced by iodine when combined with other bodies; and, consequently, when such combinations of iodine are to be examined, they should be decomposed



longing to the right prismatic system. See Figs. 258, 259, 260, 261, 262, and 263. The finest crystals are obtained from its solution in ether, or one of hydriodic acid exposed to the air. By sublimation it is obtained in laminæ, or broad oblique tables, which, when thin, transmit light of a red color, according to GIMELIN; but PAYEN states that the crystals which form under the microscope, and do not exceed in thickness the two-thousandth of a millimetre, or .000787 of an inch, are without translucency. Iodine fuses at 224.6°, and boils between 347° and 356°, giving off violet vapors, which condense upon a cold surface, producing crystals. At ordinary temperatures it is subject to spontaneous

by some strong mineral acid—sulphuric or nitric, which contains a little nitrous acid.

Iodine is a most valuable therapeutic agent, and, as such, was first brought into notice by COINDET, a distinguished physician of Geneva, who found it a most effectual remedy for goitre. Its application is very frequent, more especially in diseases of the skin, and for eradicating glandular enlargements, indurations, thickening of membranes and tumours, as well as in several other ailments. When applied to the skin, the cuticle becomes colored of an orange yellow, but this disappears after a short time. Iodine, in considerable doses, acts as an irritant poison, although to be fatal

it must be exhibited in large quantities. In the event of poisoning by this element, the pump and copious libations of amylaceous liquids should be resorted to.

MANUFACTURE.—The atomic weight of iodine has been estimated by BERZELIUS as 126; its chemical symbol is I.

Iodine has been a subject of manufacturing industry almost from the time of its discovery; and the first to prepare it on the large scale was the discoverer, but more as a *dernier ressort*, than for the sake of the advantages which it then offered. It has been stated in the foregoing, that COURTOIS was actively engaged in the manufacture of saltpetre, in which business he had invested the whole of his money; but on the throwing open of the French ports for foreign products, immense quantities of nitrate of potassa arrived from India, which at once superseded the old nitre beds, and by so doing ruined COURTOIS. In this dilemma he tried to extricate himself by manufacturing iodine; but the consumption of the article being at this time very limited, and the process of its manufacture being circuitous, rendered the enterprise an unsuccessful one. It was prosecuted, however, after COURTOIS by MM. COURNERIE of Cherbourg, in the North-East of France, who are the oldest manufacturers after the discoverer. With its extended application, as well in medicine as in printing, and latterly in photography, others were induced to turn their attention to the subject, and now several manufacturers of the article may be found, among whom may be mentioned Mr. WHITELOW of Glasgow, and Mr. JOHN WARD of the county Donegal, Ireland.

The course pursued in its manufacture is simple. The several *fuels* and *algæ* which contain it, are collected by inhabitants of places adjacent to the sea-shore, and dried in the air, after which shallow rectangular

pits are dug wherein the dried material is burned. The semi-vitrified ash that remains is broken up by sprinkling a little water upon it whilst hot. This is the *kelp* of the Scotch and Irish, and is the same as the *varec* of the Continental producers; it is purchased by the several manufacturers, in order to extract from it the iodine and other salts. For this purpose it is reduced to a coarse powder, which is placed in rectangular filters, having an inner perforated bottom of sheet-iron. These are arranged two and two, to the number of six pairs, so that whilst the one is being filled, the other is working. Water is let in upon the powder at the furthest end, till it has risen a few inches above the solid matter; and after allowing it to remain for a short time, the tap in the false bottom is opened, and the liquor drawn off as it slowly percolates through the mass.

From the receptacle in which the solution collects, it is raised by means of a pump to the second pair of filters, where it is allowed to act upon the powdered material as in the preceding instance. In the same manner the lie which is run off from each pair of filters is pumped on to the next pair, the matter in which it partly exhausts; thence it is removed to the others, and so on, till it has traversed the entire range. The solution thus obtained has a density of 1.257, and contains, for the most part, chlorides of sodium and potassium, with the iodides and bromides of these alkalies. After drawing off this first solution, the washing of the residuary mass in the filters is continued, using only as much water for this purpose as will afford a lie of 1.145 density. This is added to the other liquor, and the whole is evaporated in a series of three boilers, so disposed that the cold liquor flows into the first of the series, thence to the second, and is

Fig 264.



Fig 265



finally concentrated in the third, which is directly over the fire. Fig. 265 gives a longitudinal sectional view of the deposition of the evaporating pans, and Fig. 264 a transverse one.

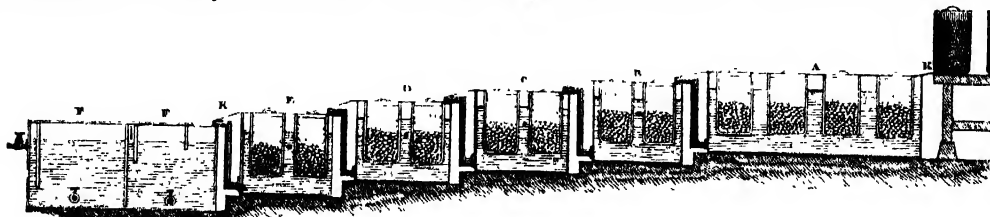
In the former of these, the pans are indicated by A, B, C, E, and F, the latter being situated over the fire, D, the flue from which passes under each in succession. After the evaporation has reduced the liquid to a density of 60° Twaddell, or 1.30 specific gravity, the chloride of sodium and sulphate of soda crystallize out in the heat, and are separated by a ladle, and thrown into an inclined drainer, C—Fig. 264—the drainings returning to the pan. When no more salt is deposited at this density, the fire is slackened, and the contents of the boiler allowed to repose for some time previous to siphoning off into wooden crystallizers lined with lead. By this a further quantity of chloride is separated in the pan, and the sulphates which are still retained are deposited in the coolers as incrustations on the sides and bottom. After removing these, and permitting the menstruum to repose for some time

longer, a crop of crystals of chloride of potassium is obtained. The period allowed for the formation of the latter deposit extends to about five days, at the termination of which, the chloride of potassium is found in large crystals at the bottom of the vessel. The mother-liquor is again pumped back into the evaporators, and reduced to 68° Twaddell, at which degree, sulphate of soda, chloride of sodium, and carbonate of soda deposit. It is customary to add sulphuric acid to the liquid in the first stages, to neutralize the carbonate of soda; the quantity of the latter which the kelp affords—about two per cent.—being thought too small to be separated from the other salts. When this is done, only sulphate of soda and chloride of sodium separate after the second concentration. The crystalline mass is then removed, and the liquor left to part with a further quantity of chloride of potassium, as in the preceding case. At this stage the mother-liquor is retained for further treatment, which will be presently described. The semi-exhausted mass is again mixed with water fractionally, till the solution marks 1.073; and the men-

strum is treated in the same manner as the first, only in a separate set of evaporators. As this contains more alkaline sulphates than the forementioned, and less chlorides, the crystallizations are effected much more readily, and when brought to about the same degree of concentration, the mother-lic, after the crystals have been deposited, is added to that from the first affusions. Finally, the washings of the residuary

mass are continued till the whole of the soluble matters are removed; these weak solutions are advantageously used to exhaust fresh portions of the kelp.

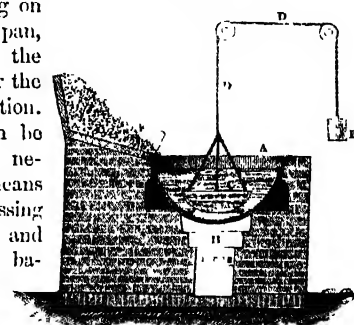
The kelp may be economically edulcorated by an arrangement such as that represented in Fig. 266, in which the parts, A, B, C, D, and E, are a number of rectangular plate-iron boxes, placed in gradation one step above another. Only five are represented in the



figure, but, if need be, a greater number may be employed. The last of these vases is a cast-iron wagon of double the size of the others, at the level of the rim of which a cast-iron plate, K, is placed in an inclined position, so that any liquid falling upon it may flow into the tank. By means of a pipe connected with A, at about six inches from its bottom, and which rises to the level of the next vessel, the liquid in A may be drawn over into B, which is similarly connected with the next, C, and so on to the vat, F, which, also by means of stopcocks, yields its contents to a series of plate-iron pans placed in gradation, like the others. The kelp or varec to be exhausted is put in small pieces into baskets of plate-iron, perforated in the manner of a skimmer, which are then introduced into the vats filled with water, by two men, who lift them by a wooden pole which passes through rings in the rim of the cylinder. After remaining in the first vat for the space of half an hour, they are transferred to the next vat, and their place replenished with two others, charged with fresh material. The same process takes place every half hour till the top wagon, A, contains two pair, at which stage those which have remained in it during an hour are taken out, and placed upon the inclined plate, K, to drain. At each succeeding half hour the transferring and charging takes place as before, the exhausted matter in the drained hampers being carried to the waste-heap. From the time, however, that the latter takes place, a portion of water, about double the volume of the perforated cylinder, is drawn off from the lower, and its place supplied from the next above it; the others in succession borrow from their superiors to the top one, which is replenished with water from the tank pipe. In this way, rapid and perfect exhaustion is insured, whilst the liquor which is drawn from E to the *settlers*, F F, has always a uniform strength. After the matter which had been retained mechanically in the liquid has deposited in F F, the lie is drawn off to the first of the evaporating pans which have been already mentioned, for concentrating the solution, in order to remove the sulphates and chlorides contained in it before recovering the iodine. Sometimes at this stage, especially when the ebullition has been quickly carried on, the chlorides and other salts which separate are in such small crystals, that they pass through the skim-

mer, and cannot be removed from the solution; hence, when the alkaline salts in kelp are procured for useful applications, there is considerable difficulty in their subsequent purification, for the sulphates and chlorides deposit promiscuously in the crystallizing pans. In order to have the separation as perfect as possible, PAYEN recommends a boiler such as that depicted in the drawing—Fig. 267—and indicated by A, having a fire beneath at B, and at the side an inclined case, F, from which the crystals are permitted to drain into the pan. A hemispherical vessel, C, of plate-iron, perforated at the sides, and resting on the walls of the pan, A, is placed in the liquid when near the point of ebullition. This vessel can be lifted out when necessary, by means of a chain, passing over pulleys, and attached to the basin at one end by branching chains, the other

Fig. 267

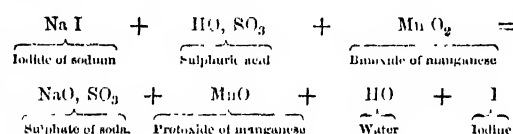


being equipoised by a weight. Ebullition of the contents of A soon takes place, and the liquid being put into violent commotion, carries the small crystals about; but as they gravitate, they fall in the centre, owing to the absence of an upward current, and are received in the vessel, C, in which they are easily removed.

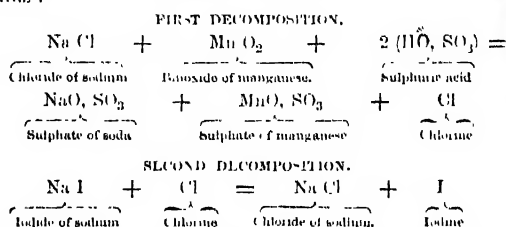
Whatever course is pursued to separate the mother-liquor from the salts, it generally happens that, in addition to the alkaline iodides and bromides, sulphide of sodium, hyposulphite of soda, with notable quantities of chlorides, are present in the solution, and which, owing to their solubility, cannot be removed. To obtain the iodine, the Scotch manufacturers add to the liquid a seventh of its volume of strong sulphuric acid, specific gravity 1.845, and, having agitated the whole, leave it to repose from thirty-six to forty-eight hours. During this period the sulphurous compounds are decomposed, sulphates being produced, whilst sulphide of hydrogen and sulphurous acid pass off, and sulphur becomes precipitated. At the end of this time the

liquor is put into a retort which is adapted to a series of receivers, and heated to 140° . Having reached this temperature, a quantity of dry powdered binoxide of manganese is introduced through a tubulure in the head of the still, and the expulsion of the iodine effected at a temperature bordering on ebullition.

The chemical change which takes place in the course of the decomposition of the iodides by the sulphuric acid and binoxide of manganese, may be indicated thus:—

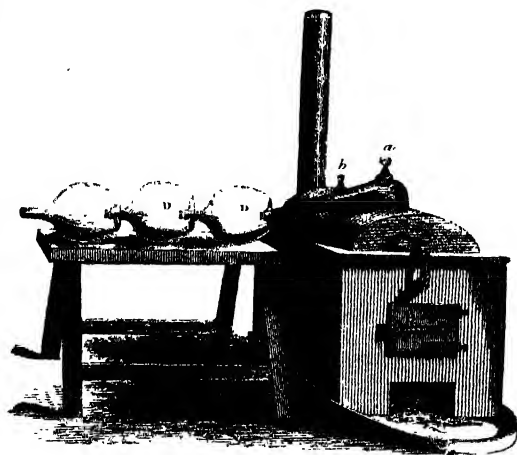


In this equation the oxygen from the manganese is represented as displacing the iodine, whilst the soda that is produced enters into combination with the sulphuric acid. Or it may be assumed that the binoxide of manganese, by acting upon the chlorides present under the influence of the excess of sulphuric acid, liberates chlorine, which in turn displaces the iodine thus:—



The distillatory apparatus employed is shown in Fig. 268, in which A is the still placed on an enclosed sand-bath over the fire, the door of which is shown at B. The head or capital of the retort is usually of lead, and is furnished with two apertures, *a* and *b*, which are closed

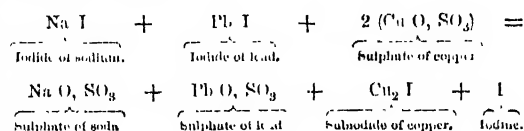
Fig. 268.



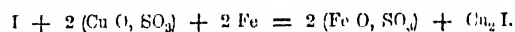
with stoppers. To the neck of the retort a series of spherical glass condensers, B, C, D, are adapted, each of which has two apertures in its axis, one of which is drawn out so as to connect it to the next, as shown in the drawing.

After charging the retort, as already directed, with the liquor, and raising the temperature to about 140° , the peroxide of manganese is added in small portions through the stopper, *a*, and the temperature raised nearly to boiling; all the orifices and joinings being previously secured with the stoppers and pipe-clay, or other luting. The iodine passes over, and is collected in flakes in the receivers. The process is examined from time to time by opening the stopper *b*, and when the passage of iodine vapors slackens, more manganese—and acid, if necessary—are introduced through the stoppered aperture *a*, and the operation conducted till the whole of the iodine has separated. Such is the method pursued by Mr. WHITELAW of Glasgow, with this slight difference: he adds only an eighth part of sulphuric acid gradually to the liquor in a leaden boiler, and allows the sulphate of soda to crystallize out before introducing it into the still. It is important to retain the temperature at which the distillation proceeds at 212° , or nearly so, for above this the iodine is liable to pass over as chloride.

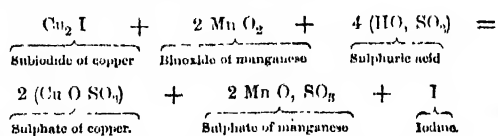
Sometimes, when the process is conducted in the manner just described, cyanide of iodine is produced, and is found in the third receiver in white needle-shaped crystals. The residue in the retort still retains some iodine in the form of iodide of lead and sodium. This can be recovered by the method proposed by SOUBEIRAN—namely, the addition of sulphate of copper, by which a subiodide of copper is formed. The precipitate is filtered, and the filtrate, which still retains some iodine, treated with a further quantity of the cupreous salt and iron filings, when another interchange takes place, and a further precipitation of iodide of copper occurs. The first of these changes may be expressed thus:—



And the second, by

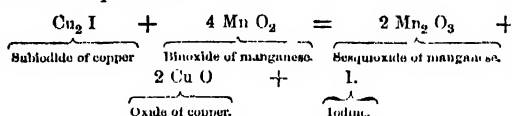


The proper period for arresting the addition of the cupreous salt and filings in the latter case, is when the characteristic smell of iodine disappears. No time should be lost in removing the precipitate from the ferruginous salt and filings by washing and decanting from the fragments of iron, and subsequently filtering through a cloth. Both portions of iodine are desiccated at a gentle heat, and the dry compound mixed with twice or three times its weight of peroxide of manganese, and as much strong sulphuric acid as will form it into a paste, and the mixture strongly heated in a subliming apparatus, when iodine passes off and is received in appropriate vessels: thus—



The use of sulphuric acid may be dispensed with in

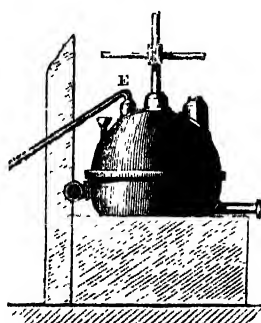
the above process, but the heat must be much more elevated when that agent is not employed. In this case, the binoxide of manganese is decomposed into sesquioxide of manganese and oxygen, which displaces the iodine combined with the copper, as shown in the annexed equation:—



According to SOUBEIRAN, this method is very economical, and affords as much as one per cent. of the mother-liquor operated upon.

At the Cherbourg Works the mother-waters are treated in slight excess with sulphuric acid, and the solution is afterwards boiled for some time; during this operation the sulphides, hyposulphites, and sulphites are decomposed, sulphurous acid, *et cetera*, being eliminated, and sulphur precipitated. Some time is now allowed, in order that the solution may clarify, and when this is effected, the supernatant fluid is drawn off from the precipitate and diluted till it marks 40° Twaddell, and then chlorine passed into it to saturation from a generating apparatus, such as that shown in Fig. 269. The chlorine passes off from the stills, A, B, where binoxide of manganese and hydrochloric acid are made to

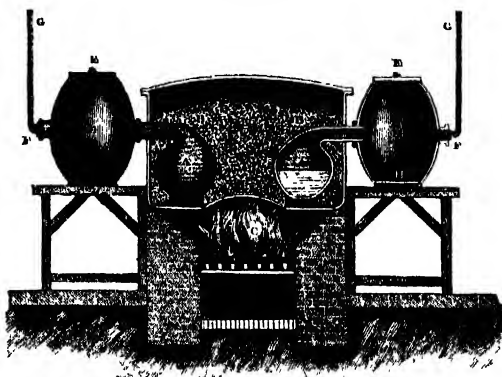
Fig. 269.



act upon one another, or chloride of sodium, sulphuric acid, and binoxide of manganese, and proceeds by the conduit, E, into the vat, where it liberates the iodine from its combination in the mother liquor. The end of this operation is the decomposition of the iodide present, or rather of the hydriodic acid, and the evolution of the iodine by the substitution of the chlorine; the iodine, being only slightly soluble, precipitates. In transmitting the chlorine through the liquid, it is necessary to guard against two evils: the first arising from the use of this agent in insufficient quantity, for in this case the iodine compound remains in part underdecomposed; the second, produced by an excess of the gas, owing to the formation of chloride of iodine, which passes off in vapor, and is lost. Hence, to determine the exact point, it is necessary to test a part of the liquid as well with chlorine as with a solution of iodide of potassium, to prove, on the one hand, if there remains any further portion of the salt unacted upon; and on the other, if the agent be present in excess. Should the latter be the case, a further addition of mother-liquor is made to combine with the free chlorine. When the decomposition is complete, the contents of the vessel are allowed to settle, and after a time the clear liquor containing chlorides and sulphates is drawn off from the iodine. The latter is repeatedly washed by decantation, till the washing gives no indication by the hydrometer of the

presence of salts. The iodine is afterwards put and left to drain in a conical vase of pottery-ware, the bottom of which is perforated and rests upon a jar of freestone; it is then dried upon sheets of filtering-paper laid upon well-dried cinders, or upon porous tiles.

Fig. 270



The next step is the purification by a process of sublimation in an apparatus like that shown in Fig. 270. The iodine is introduced into the retorts, A, A, which form a gallery of two rows, to the number of six; they are immersed in the sand of the cast-iron case, B B, which is heated by the fire, C. Into each of these about forty-five pounds of the crude iodine are introduced; they are then wholly buried in the sand, the neck as well as the body of the retort. This precaution seems necessary, to prevent the condensation of the iodine vapors in the neck, and the obstruction of the passage which would ensue. That this may be guarded against as much as possible, the necks of the retorts are short, and the receivers placed in connection with them as close to the sand-bath as possible. An elliptical cistern, D D, is used for this purpose, the beak of the retort entering at the side. It is furnished with a movable cover, E, to facilitate the removal of the iodine; it has likewise a perforated plate at the bottom, H, to allow any water which may condense to drain off. A tubulure, F, at the opposite side to that which receives the beak of the retort, allows the vapor of water to pass off by the pipe, F G, out of the range of the operation. In this way the iodine is obtained in fine large crystals.

When the bromine which is present is to be recovered, the liquor drawn off from the precipitate is evaporated to dryness, the residue compounded with sulphuric acid and binoxide of manganese, and distilled from a leaden vessel. Bromine passes over, and is received in strong sulphuric acid, in which it sinks, and is thus prevented from fuming, and injuring the health of the workmen.

IMPROVED PROCESSES.—BARRUFL's process resembles the last in some of its operations. The remaining mother-liquor is evaporated to dryness, the residue mixed with about one-tenth of its weight of binoxide of manganese, and then heated to about incipient redness, the mixture being kept stirred all the time. The heat is continued till the sulphides and hyposulphites

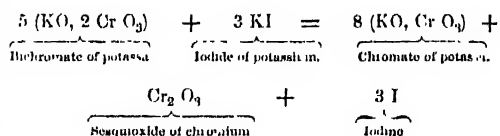
are thoroughly oxidised, which is known by treating a sample of the substance with sulphuric acid, and observing if sulphide of hydrogen be evolved. In this operation the heat should not be raised to such a degree as would cause the evolution of iodine, of which the characteristic violet vapor would be an indication. Water is added to the mass, and the sulphates and iodide of sodium are washed out; using only as much water, however, as will afford a solution of 36° Beaumé. Chlorine gas is now passed through the filtrate, and the iodine which is precipitated purified, as described in the preceding method.

In order to avoid the loss of iodine consequent upon the burning of the plants for the production of kelp, Dr. KEMP suggests a method whereby the iodine may be extracted, and the burning—as in the production of kelp, by which, doubtless, much iodine is dispersed—dispensed with. His suggestion is to crush the roots which contain the largest proportion of iodine, and to set them by in a heap, tank, or any convenient vessels, for a few days, and after the fermentation which ensues has subsided, to extract the soluble salts, among which will be the chief portion of the iodides, with cold water slightly acidulated with ordinary hydrochloric acid. This liquid is to be then treated with chloroxide of calcium—bleaching powder—in slight excess, so as to liberate the iodine, and the latter precipitated by adding to the liquid a sufficient quantity of amido-acetate of lead—prepared by adding a solution of tribasic acetate of lead to well-washed potato starch—by which the whole of the iodine is carried down. The precipitate may be washed and dried, and in the hands of the manufacturer the iodine may be removed from it by adding a solution of sulphide of potassium, which precipitates sulphide of lead, leaving iodide of potassium in the liquid. After filtration the liquid may be concentrated, and the iodine extracted by one or other of the processes mentioned. The fluids from which the precipitated compound of iodine and amido-acetate of lead is separated, may be useful in an agricultural point of view, either for mixing in the compost heap, or with other liquids in the manure tank. The cakes of cellular tissue which result from the pressure of the material after fermentation, may be dried and used as fuel; the ashes being preserved, on account of the portion of iodine they still retain, as well as for the other salts, which are valuable, both in an agricultural and manufacturing point of view.

Professor BECHI has indicated a process by which iodine may be economically obtained from river and other waters containing it in small proportion. His method of procedure is, to treat the waters with a mixture of one part of sulphuric acid and two of nitric, and to pass the acidulated liquor into a tank or vat, having a funnel-shaped bottom, and filled with lamp-black that has been heated to redness, or well-made ivory-black. The acids have the effect of removing the bases from the iodine, and on transmitting the solution through the charcoal, the latter is retained. When the lamp-black is charged with the iodine, and it is desired to obtain it, a solution of potassa is added, or what is better, the carbonaceous matter is mixed with hydrated protoxide of iron in a tub. After a

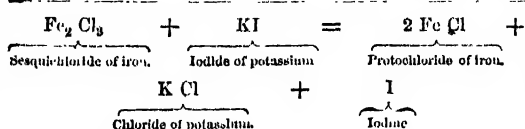
while the iodine is taken up, and an iodide of potassium or of iron produced. When the action has been sufficiently completed, water is allowed to flow upon the mass to dissolve these salts, the solution being drained off in another funnel-shaped vessel, which is stopped in the tube part with sponge or other porous material. The liquor is evaporated to dryness; and, in case of potassa being used, the iodide and iodate are decomposed by sulphuric acid and binoxide of manganese in the manner described in the foregoing. The iodide of iron may be operated upon in the same way; or, if it be thought better to dispense with the evaporations, a sulphate of copper solution may be added, and the precipitate of subiodide of copper, which falls after filtration and washing, distilled with sulphuric acid and binoxide of manganese, *et cetera*.

In a paper by SCHÖNBEIN—see *Chemical Gazette*, vol. viii., p. 166—several substances are described which are able to decompose the alkaline iodides, so as to liberate the non-metallic element in the dry way. Such are the metallic oxides and acids, containing two, three, and five equivalents of oxygen; but many seem to exercise an unequal degree of power in effecting this change. The most remarkable are arsenious acid, chromic acid, sesquioxide of iron, and protoxide of copper; but there is danger in employing the first of these, lest a portion of the poison might be driven off by an increased temperature with the iodine, and thus render its application dangerous as a therapeutic agent. When three parts of bichromate of potassa are ground and mixed with two of iodide of potassium, and the mixture is submitted to dry distillation in a stoneware retort, the whole of the iodine is set free, leaving in the vessel a greenish mass, which is a mixture of chromate of potassa and sesquioxide of chromium. The decomposition is represented by the following equation:—

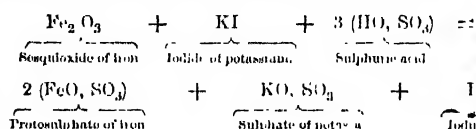


The iodine which is thus produced is very pure, and no loss either of it or the reagent is experienced; for the chromate, which is a residuary product of the distillation, is a valuable salt, and applicable for many purposes; whilst the green sesquioxide left after washing away the former, may be employed as a pigment in painting upon porcelain, *et cetera*; or by fusing it with an alkaline nitrate and carbonate, it may be reconverted into a bichromate of the alkali, which may be employed to decompose a fresh portion of iodide.

Iodine is also set free when anhydrous sesquichloride of iron is mixed with iodide of potassium, even at ordinary temperatures; and, on the application of heat, it passes off in dense vapors, which may be received in the usual manner. The change of the substances in this instance is due to the reduction of the ferruginous sesquisalt to that of a protosalt; the liberated equivalent of chlorine assimilating with the potassium, and thus setting the iodine free:—



Sesquisulphate of iron may be advantageously substituted for the preceding salt; for, when an alkaline iodide is moderately heated with it, dense vapors of iodine are liberated, quite free from sulphurous acid or other impregnation. Hence, by employing sesquioxide of iron and iodide of potassium in equivalent proportions, and adding to the mixture three equivalents of sulphuric acid, so diluted as not to be able by itself to liberate iodine, then moderately heating—the whole of the iodine passes over into the receiver, and the residuary matter is composed only of sulphates of potassa and of iron, as may be seen by the subjoined formulæ, representing the interchange which takes place:—



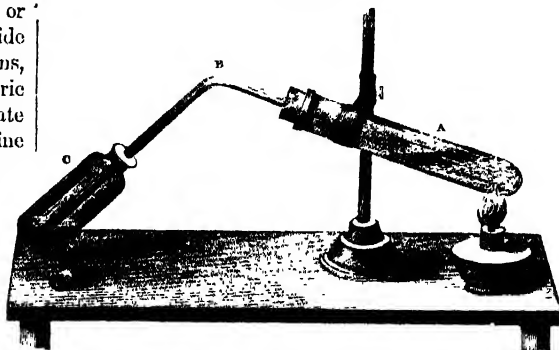
COMBINATIONS OF IODINE.—Allusion has already been made to the compounds which iodine forms with some of the other elements; and a short description of the more important and useful products formed by combining this element with others, both of a metallic and non-metallic nature, will now be given.

All the non-metallic elementary bodies, with the exception of fluorine, are capable of entering into combination with iodine, either in single or multiple proportions, and many of these compounds are so persistent as to offer considerable resistance to opposing affinities before being resolved into their elements. Like chlorine, sulphur, phosphorus, *et cetera*, iodine constitutes with hydrogen and oxygen acid compounds which, in their general characteristics, are analogous in every respect. With nitrogen and ammonia it affords a compound which is eminently explosive, but with the other simple bodies its combinations offer little interest beyond the precincts of the laboratory. Many of its compounds with the metals are very valuable, as well in medicine as in many branches of industrial art; and to the chemist they are in frequent demand as effective reagents both for ascertaining the presence and estimating the proportion of numerous bodies. Of these, however, reference will be made only to those of alkali metals, iron, silver, mercury, and a few others.

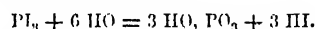
IODIDE OF HYDROGEN—Hydriodic Acid—Iodhydric Acid.—Next to oxygen, chlorine, bromine, and fluorine, iodine manifests the greatest affinity for hydrogen; consequently, it abstracts this element from its combinations of phosphide of hydrogen, sulphide of hydrogen, ammonia, as well as from alcohol, ether, and volatile oils; in each instance hydriodic acid results. A similar metamorphosis with regard to the iodine takes place when it is mixed with water in the presence of a body capable of abstracting oxygen from the latter; and by this means hydriodic acid is sometimes prepared. Thus, when a mixture of nine parts of iodine and one of phosphorus is introduced into a tube,

A—Fig. 271—and covered with moist quartz, sand, or powdered glass, and heat applied, decomposition of iodide of phosphorus, which is at first formed, takes place, as it comes in contact with the thin stratum of moisture, and hydriodic and phosphorous acid are produced; the former being volatile, may be conducted by

Fig 271.



a tube, B, to the receiver, C, in which it may be collected. The change of elements in the reaction alluded to may be expressed thus:—



Only a slight heat should be applied to produce this decomposition, for, if the temperature be elevated, some terhydride of phosphorus is apt to form and pass over into the receiver, and contaminate the hydriodic acid. Another method is to compound one part of phosphorus, fourteen of iodide of potassium, and twenty of iodine, with a little water, and submit the mixture to heat in a retort or distillatory vessel fitted up on the principle of the apparatus in the preceding figure. When the evolution in this case becomes too rapid, the retort should be cooled by plunging it in cold water; and, on the other hand, when it slackens, the heat must be reapplied.

Several modes may be adopted for preparing this acid in the liquid state: thus, iodide of barium or of lead may be decomposed by an equivalent proportion of sulphuric acid, and the liquid, after filtering off the insoluble precipitate of sulphate of baryta or of lead, concentrated; this product will be aqueous hydriodic acid. Iodine is diffused in water, and sulphide of hydrogen transmitted through it, when decomposition of the latter takes place, sulphur being precipitated, and hydriodic acid produced. A difficulty is, however, experienced in this process, notwithstanding its being effectual—namely, the evisceration of a portion of iodine by the depositing sulphur, by which the whole of the former cannot be conveniently transformed in its hydracid. DUMAS proposes to remedy this defect by merely saturating a given volume of water with iodine, and, after allowing the insoluble portion to subside, and decanting the brownish fluid, he directs that the sulphide of hydrogen should be passed through it till it becomes colorless. The deposited sulphur is then filtered, and the filtrate again charged with the iodine, and the portion which dissolves again acted upon as before. In this way the whole of the iodine may be

converted into the acid; for at each succeeding saturation, in consequence of the portion of hydriodic acid that is formed, the liquid acquires the property of dissolving a larger quantity of the iodine. The process is troublesome, however, from the repeated filtrations and solutions. Hydriodic acid might be obtained with considerable facility by passing the gas through a solution of iodine in alcohol, were it not that some sulphide of carbon would be produced by the action of the sulphur on the spirit, and which could not be conveniently removed.

Hydriodic acid, prepared according to the first of these methods, is a colorless gas, soluble in water, and capable of strongly reddening litmus; it has an acerb taste and very pungent odor, somewhat similar to hydrochloric acid. When allowed to escape into the air, it produces dense white vapors, which are very suffocating when inhaled. Its density is 4.3757, according to THOMSON, but GAY-LUSSAC gives it 4.4429, air being taken as unity; it is neither a combustible body nor a supporter of combustion. Steam, sulphurous acid, chlorine, bromine, and a few other bodies, are capable of decomposing hydriodic acid with the separation of iodine in every instance. The gas is composed of half a volume of iodine and half a volume of hydrogen. In the liquid state hydriodic acid is colorless, and of a specific gravity 1.700. It is highly acrid, and possesses an odor similar to that of the gas. Upon exposure it gradually suffers decomposition, being converted into hydriodous acid with the evolution of hydrogen; but, with prolonged contact with the air, the oxidised portion reacts upon the remainder, and causes the liberation of the iodine, which separates in fine lamellar crystals.

Sulphuric acid, when concentrated, sets free the iodine, a portion of the agent being at the same time broken up into sulphurous acid and oxygen. Hydriodic acid has been solidified by FARADAY at a temperature of -59.8° Fahr. In this state it is perfectly transparent and colorless, but intersected with fissures like ice. The tension of the vapor at 0° is 2.9 atmospheres.

This acid is capable of decomposing the oxides of most of the metals affording metallic iodides and water. Its symbol is HI , and its atomic weight 127.

Iodine forms, with oxygen, compounds of various degrees of oxidation, the lowest being iodic oxide— IO , and iodosous acid— IO_2 ; the highest iodic acid— IO_3 , and periodic acid— IO_7 . The latter three constitute salts with the metallic bases, which are called iodites, iodates, and hyperiodates respectively. To enter into a description of the processes by which they are prepared, would not be warranted by the uses which they serve—namely, of forming the links of analogy between iodine and chlorine, bromine, *et cetera*.

With sulphur, phosphorus, chlorine, and bromine, it produces several compounds, which are very interesting to the chemical student. The combination of iodine with nitrogen is remarkable, in being analogous to the chloride of this element, although the explosion which it produces is much less violent.

Iodide of Nitrogen.—If dry iodine and ammonia are brought together in close vessels, they form a brownish liquid, which is simply a combination of the two sub-

stances, and which may be represented by the formula $3(\text{NH}_3) \text{I}_2$. When, however, the iodine is digested with a strong solution of pure ammonia, the compound in question falls as a black powder. The same change takes place when carbonate of ammonia is substituted for the caustic alkali, or chloride of iodine for the pure element. To favor the reaction in this case, the mixture of the ingredients should be effected with a gentle abrasion in a mortar. The powder should be washed on a filter with water, to remove the excess of ammonia and the iodide of ammonium which forms. Another method for preparing the compound with equal facility, but without incurring the risk of spontaneous explosion, is to dissolve the iodine in alcohol 54.5° Twaddell, and, after decanting the tincture, saturating it with a strong solution of caustic ammonia. After briskly agitating, the mixture is diluted with water upon which the iodide of nitrogen precipitates, and may be washed in the cold with this liquid either by subsidence and decantation, or on the filter. The iodide thus produced is not spontaneously decomposed; but SERULLAS remarks, that if the iodine be precipitated from the alcoholic solution by water, and the solid thus recovered treated with ammonia, a compound results which is very apt to explode even during the preparation. Subsequently to the affusion, the compound is dried carefully upon bibulous paper at the ordinary temperature. In performing this operation, care should be taken to divide the mass into small portions, which ought to be placed at a distance from one another, in order to preclude the possibility of an explosion of any considerable quantities of the salt.

MILLON states that it may be desiccated with safety in a bell surcharged with ammoniacal gas, and no decomposition occurs even after lengthened exposure, provided the atmosphere is one of ammonia.

The slightest cause is adequate to decompose the iodide of nitrogen with a violent explosion, and the evolution of a violet light which is visible in the dark. The feather of a quill drawn over the powder is sufficient to produce this effect, and if contained in a dish in moderate quantity, the force is such as to shatter it in pieces. Even if rubbed strongly under water, an explosion takes place; but the causes which determine this change in the air are incapable to effect the decomposition when it is mixed with large quantities of water. It is not liable to explode by mere contact with oils and fats, like the chloride of nitrogen. The products of the decomposition of this peculiar salt, so far as they have been examined, seem to be pure nitrogen, finely divided iodine, and hydriodic acid; but some assert that iodide of ammonium is produced. MARCHAND found that traces of the latter salt were formed upon the sides of a glass jar, in which portions of the nitrogenous compounds had been successively exploded. Water gradually dissolves the iodide of nitrogen with the formation of iodide and iodate of ammonia, free iodine, and the evolution of small quantities of nitrogen. By the action of heat, or sulphuric or nitric acid, the action is considerably expedited. Sulphide of hydrogen effects an immediate decomposition of this compound, the products being iodide of ammonium, hydriodic acid, and sulphur; the alkalis; lime, *et cetera*, operate in a

similar way with the liberation of ammonia, and the formation of an alkaline iodide and iodate.

Composition of Iodide of Nitrogen.—The composition of this body is as yet somewhat doubtful, being regarded in the several lights of iodide of nitrogen— NI_3 , iodide of amidogen— NH_2I , or as a mixture of the former of these with an equivalent of ammonia. The following are the data furnished by the calculations of the investigators whose names are attached:—

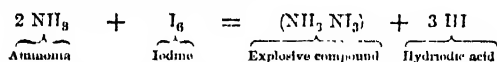
GAY-LUSSAC.

A			
			Centesimally
1 Eq. of Nitrogen.....	14	=	3.57
3 Eqs. of Iodine.....	378	=	96.43
	392	=	100.00

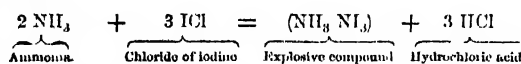
B			
			Centesimally
1 Eq. of Nitrogen.....	14	=	10
1 Eq. of Iodine.....	126	=	90
	140	=	100

MILLON.			
			Centesimally
1 Eq. of Amidogen { 1 Eq. N = 14		=	986
2 Eq. H = 2		=	1.11
1 Eq. of Iodine = 126		=	88.73
	142	=	100.00

According to the recent analysis of BUNSEN, however, it appears that the composition of the compound is NI_3 , NH_3 , but that another compound of these elements exists, presenting the composition indicated by the formula 4 (NI_3), NH_3 , and which results from the precipitation of an aqueous solution of chloride of iodine by ammonia. In either case he regards these iodides as ammonia compounds, in which the hydrogen is entirely replaced by iodine, and which unite with an equivalent of undecomposed ammonia, as expressed by the formulæ. He gives the equation representing the formation of this explosive body by the mutual action of iodine and ammonia, thus—



And by the effects of ammonia upon chloride of iodine thus—

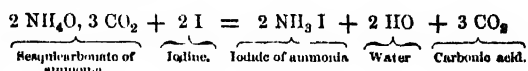


Combination of Iodine with Metals.—With most of the metals iodine enters into combination, producing metallic iodides, but, in forming such, very diverse phenomena are exhibited; some are produced instantaneously, on account of the force of the affinity which exists between the elements, whilst others require very careful and circuitous manipulations, in order to effect the union of both substances.

Only a few of these combinations have been brought into use in the arts and sciences, consequently it will be unnecessary to pursue their description beyond those compounds which are available in medicine, photography, *et cetera*. Such are the alkaline iodides, iodide of iron, of mercury, and of silver, with a few others.

Iodide of Ammonia.—When dry ammoniacal gas and iodine are brought in contact, combination takes place, and a heavy blackish-brown, very tenacious

liquid is produced; the same compound is obtained on gently heating equal weights of sesquicarbonate of ammonia and iodine in a retort or porcelain tube, water and carbonic acid being formed. The change may be expressed thus—



The compound is easily decomposed in part when heated, ammonia being set free; the chief portion of the iodine salt, however, sublimes in violet-colored vapors. It indicates the presence of ammonia and iodine. Its composition, according to MILLON and BINEAU, is—

MILLON.

	At weight	Centesimally
1 Eq. of Ammonia,	17	= 11.89
1 Eq. of Iodine,	126	= 88.11
$\text{NH}_3 \text{I}$,	143	= 100.00

BINEAU.

	At weight	Centesimally
3 Eqs. of Ammonia,	51	= 18.02
2 Eqs. of Iodine,	252	= 81.28
$3 \text{NH}_3 2 \text{I}$,	283	= 100.00

Iodide of Ammonium.—The compound which is met with in commerce, and intended chiefly for the photographer, is prepared by neutralizing a solution of ammonia with hydriodic acid gas, and subsequently decomposing any iodate of the alkali, by transmitting a slight excess of sulphide of hydrogen through the liquid, evaporating the liquor in a water-bath, and afterwards filtering off any deposited sulphur. When the evaporation is conducted carefully under the bell jar of an air-pump, the salt crystallizes in cubes and is colorless; but if exposed to the air, it readily deliquesces, and turns brown, owing to a portion of the iodine being set free. It may be prepared likewise by bringing ammoniacal and hydriodic acid gases in contact, or by decomposing iodide of iron by carbonate of ammonia, filtering off the ferruginous precipitate, and evaporating the solution till the iodide crystallizes.

The iodide of ammonium thus prepared is a very deliquescent salt, very soluble in water and alcohol. By keeping, even in diffused daylight when out of contact with air, it decomposes, turning brownish-yellow, ammonia being evolved. It may be represented as $\text{NH}_4 \text{I}$, or $\text{NH}_3 \text{HI}$, and its per centage composition as—

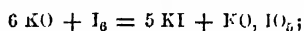
	At weight	Per cent
1 Eq. of Ammonium,	18	= 12.50
1 Eq. of Iodine,	126	= 87.50
$\text{NH}_4 \text{I}$,	144	= 100.00

Iodide of Potassium.—This salt is one of the most valuable compounds of iodine; its importance is derived from its medicinal effects chiefly; but as a reagent in the laboratory and in photography it is, especially for the latter, in general use. There are several recipes for preparing it, the most appropriate of which will be here noticed.

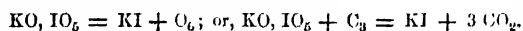
When potassium and iodine, or iodine vapor, are

brought together, rapid combination takes place with a considerable rise of temperature, and the evolution of a violet light. If the combination be aided by heat, the union of the two elements is often attended with a violent explosion. The result is iodide of potassium.

To prepare this body with materials which are more easily obtained, and at less expense and trouble than potassium, other processes are adopted. The simplest of these appears to be the following:—Powdered iodine is agitated with a solution of caustic potassa as long as the former dissolves. Its point of saturation is known by the liquid acquiring a brownish tint. When this happens, any excess of iodine is removed by subsidence and decantation of the liquor, or it is acted upon by a proportionate quantity of the alkaline lie. By evaporation there is obtained a white residuary mass, consisting of iodide and iodate; the latter is decomposed by heating the mass gently for some time, when iodide of potassium only remains. There is need, however, of giving particular attention to this part of the operation; for if the temperature be too elevated, some loss of iodide of potassium by volatilization is sustained; and, on the other hand, if too low, portions of iodate remain undecomposed and contaminate the salt. To avoid this, ORFILA, and latterly SCANLAN, recommend to mix the dry residue with charcoal-powder before submitting it to the action of the heat; this has the effect of bringing about a more perfect decomposition, and at a lower temperature, than could be effected without it. No iodine is liberated, and the whole of the oxygen of the iodate is taken up by the carbon, which is thereby converted into carbonic acid. After heating, the mass is exhausted with water, which dissolves out the iodide. Alcohol may be substituted with advantage when a very pure product is desired, for this takes up only the iodide and leaves the carbonate of potassa, which is nearly always present. By distillation the spirit may be removed, and the iodide crystallized from the concentrated alcoholic solution, or from water. If the residue, after the first evaporation, be treated with alcohol only, the iodide of potassium dissolves, the iodate and any carbonate which might have been present in the alkaline liquor remaining behind. This residuary salt may be afterwards heated with charcoal, and the iodide to which it is reduced extracted as above. In both cases the changes which occur may be thus symbolized:—



The final product by the application of the heat becoming iodide of potassium, thus:—



The method of saturating a solution of potassa, or of carbonate of potassa, with hydriodic acid, offers very good results, were it not that the preliminary operation involved in the preparation of the hydriodic acid renders the course rather circuitous. By forming an iodide of zinc, as recommended by LE ROYER and DUMAS, the operation is shortened and simplified. Zinc turnings, water, and iodine are agitated together in a close vessel, and the metallic salt which is thus produced is afterwards decomposed by addition of carbonate of potassa

to the liquid as long as a precipitate appears. The carbonate of zinc is filtered, and the solution evaporated to the crystallizing point. This method is objected to on account of the difficulty which is experienced in removing the last traces of iodide of zinc. In order to obtain a pure salt by this process, GIRAULT gradually pours the cold solution of the iodide of zinc into a boiling hot one of carbonate of potassa as long as there is any effervescence observed; cold water is then added to the mixture, and the whole filtered, and the carbonate of zinc washed twice with water. The trace of zinc still held in solution is removed by the cautious addition of carbonate of potassa, the precipitate filtered, and the liquid concentrated and set by to crystallize. By many iron is substituted for the zinc, but the further steps in the process are decidedly the same. Two parts of iodine, one of iron, and ten of water are agitated together in a close vessel till the liquid loses its brown color; as soon as this happens, the liquid is filtered, and precipitated by a solution of caustic or of carbonate of potassa heated to the seething point. Care must be taken that the air is as much as possible excluded during the production of the iodide of iron, so as to prevent the formation of a basic iodide of this metal, which could be decomposed only by an excess of alkali.

The Dublin college directs the conversion of the iodine into hydriodic acid by sulphide of hydrogen, and the neutralization of this product either by potassa or carbonate of this alkali. TADDIE employs an alcoholic solution of iodine, or iodine diffused in water, and adds to it an aqueous or alcoholic solution of sulphide of potassium till the whole becomes colorless. Sulphur which separates in this operation is removed by filtration, and the liquid evaporated to obtain the salt in a crystalline state. It may be observed that in this process, when alcohol is employed, the iodide of potassium is always more or less of a brown color. Further, when the sulphide of potassium is present in excess the liquid becomes cloudy, to remove which a greater quantity of iodine must be added. Notwithstanding these precautions, it appears, that the iodide of the alkali produced is, to some extent, impregnated with sulphur; for upon heating, it turns grey, and evolves sulphide of hydrogen. The process recommended by STEPHANI is merely the old one of TURNER, mentioned above, modified. Into a bath of the caustic alkali, iodine is introduced in small portions at a time until the liquid begins to be tinged. The weight of iodine necessary to effect this is found by having a determined quantity of iodine to begin with, and weighing what remains. After the point of incipient coloration is observed, as much more iodine as is already contained in the liquid is to be added, and the whole agitated until it dissolves. Iodide of potassium and iodate of potassa are thus produced, and by treating the liquor with sulphide of sodium, prepared by saturating a solution of an equal quantity of alkali to that to which the iodine was added with sulphide of hydrogen; both liquors are mixed and left to repose, when, by mutual decomposition, the contents of the vessel become muddy in consequence of the deposition of sulphur; after a short interval this sulphur falls to the bottom, when the whole is passed through a filter, and the percolating liquid concentrated so as to obtain the salt.

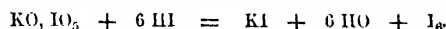
STEPHANI states that very beautiful transparent crystals are obtained in this way, and which are quite different in this respect from the salt met with in the market.

Iodide of potassium crystallizes from its aqueous solution in the form of cubes, parallelepipeds, pyramids, or octahedrons; and, according to KANE, sometimes in forms belonging to the square prismatic system. The crystals are soluble in about three-fourths of their weight of water at ordinary temperatures, and in six parts of alcohol of 0.85 specific gravity. By this solution in water the temperature is reduced about 75.2°. The boiling point of the saturated solution is about 248°. The salt melts at a temperature below redness, and forms pearly crystals on cooling; if air be admitted to it whilst in a state of fusion, a portion volatilizes undecomposed. SCHINDLER found, when performing the experiment in glass tubes, that the volatilization does not take place below the fusing point of the glass. Chlorine, sulphurous acid, sulphuric and nitric acids, are capable of decomposing iodide of potassium, yielding iodine in the free state; or, in the case of sulphuric acid when diluted, hydriodic acid, as noticed under the manufacture of iodine. According to GAY-LUSSAC, it may be represented by KI being composed of—

		Cent. grains
1 Eq. of Potassium	39	= 25.63
1 Eq. of Iodine,	126	= 76.37
1 Eq. of Iodide of potassium....	165	= 100.00

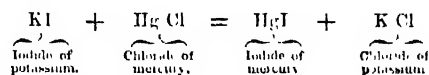
The iodide of potassium is liable to much adulteration, as well from the nature of the processes followed in its manufacture, as from intentional additions of other bodies of less value. Those bodies, the presence of which is consequent upon the method of manufacture, are carbonate of potassa, chloride of potassium, sulphate of potassa, iodate of potassa, and, under particular circumstances, traces of a substance known as xanthate of potassa. Carbonate of potassa, derived from the imperfect neutralization of the iodide or hydriodic acid, in the first instance, may be discovered by the effervescence which succeeds the addition of hydrochloric acid to a portion of the salt, and also by its solution giving a precipitate with lime water; this impurity remains undissolved when the salt is treated with alcohol. Traces of alkaline chlorides may be derived from its being contained in the alkali taken to prepare the salt. Their presence is detected by its giving a precipitate with nitrate of silver, which is soluble in ammonia, and is reprecipitated from this solvent in the state of white chloride of silver by nitric or sulphuric acids. Sulphuric acid is detected by adding to a weak acid solution a few drops of chloride of barium. Alkaline sulphates are also left undissolved when a portion of the sample is treated with alcohol. Xanthate of potassa is produced when the iodide is prepared by the action of sulphide of potassium or of barium upon iodine dissolved in alcohol. When this body is present, the taste of the salt is like that of asafetida; it turns greyish-brown on being heated, and evolves sulphurous acid; when the heated residue is treated with water, a substance remains undissolved

which is composed chiefly of carbon, but traces of sulphates are found in the solution. Iodate of potassa is detected by adding a weak acid, by which hydriodic acid is liberated; this effected, the liberated hydriodic acid exercises a deoxidizing effect upon the iodate, its hydrogen combining with the oxygen of the iodic acid of the latter, and setting the iodine free. Thus—

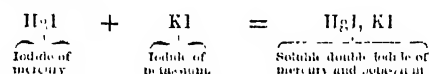


Such disengagement of iodine is indicative of the presence, not only of an iodate, but likewise of any other of the higher oxygen acids. Exclusive of the substances mentioned, and which are never contained in greater proportion than one to two per cent., adulteration of this salt has been known and detected to the extent of seventy and eighty per cent.

Besides the process, which will be detailed at the end of this article, for the analysis and determination of iodine, as well in the commercial article as in the iodides of the metals, a simple process, applicable for the estimation of the amount of iodide in the alkaline salts, may be here mentioned. It is founded upon the behavior of the alkaline iodides with chloride of mercury, whereby an equivalent of either the potassium or sodium salt precipitates exactly an equivalent of chloride of mercury in the form of iodide. The insoluble compound thus formed is, however, redissolved by a second equivalent of the alkaline salt, in consequence of the production of a soluble double iodide of mercury and potassium. The reactions may be expressed thus:—



And secondly—



To test the salt, two equivalents—330 parts—and one equivalent of chloride of mercury—135.5 parts—or any less weight of each, provided this ratio is retained, are weighed and dissolved in equal measures of water, say one thousand grains. To the solution of the iodide the mercurial liquor is to be added till a permanent precipitate appears. Should it happen that no turbidness arises, even when the whole of the latter liquor has been added, it is a proof that no adulterant exists in it; but if a precipitate should occur when only the one-half or one-fourth of the mercurial liquor has been poured in, it is evident that the iodide must be adulterated with one-half or one-fourth of some spurious matter. When iodide of sodium is to be tested in this way, it will be clear that the weight of the salt to be taken will differ from that specified for the potassium salt, in proportion as its equivalent weight is less; that is, only two hundred and ninety-eight grains are required.

Iodide of potassium is used in the laboratory as an agent for producing metallic iodides, and by the photographers largely, in preparing the silver baths wherein the plates are immersed; its chief application

is in the latter art, and in medicine. Its medicinal properties are, in a great measure, similar to those of iodine itself. For further information on its physiological properties, the reader is recommended to consult the able work of the late Dr. PEREIRA.

Iodide of Sodium.—The description given for the obtaining of the preceding iodide will fully answer for the manufacture of this compound. The crystals, however, retain four equivalents of water when they form in an aqueous solution of the salt; they are larger than those of iodide of potassium, and present the appearance of oblique rhombic prisms; they melt in their water of crystallization when heated, giving the anhydrous salt; if the temperature be maintained, they dissolve in 0.6 parts of cold water. According to MITSCHERLICH, it is composed of—

	Centimally			
		Theory	Mitscherlich.	
1 Eq. of Iodide of sodium	= 149	= 80.21	= 80.6	
4 Eqs. of Water	= 36	= 19.79	= 19.4	
	185	100.00	100.0	

Symbol, Na I, 4 H₂O.

Iodide of Iron.—This salt, as already intimated, is prepared by agitating water and iron turnings, or fine wire, and iodine together, taking the precaution to retain the presence of an excess of the metal. The iodine attacks the metal, and combines with it, forming a soluble iodide of iron. The compound, though readily prepared in the state of solution, is more difficult to obtain as a solid, owing to its tendency to decompose, yielding free iodine and a basic iodide, which is but sparingly soluble. During the concentration of the solution of iodide of iron this change occurs, unless it be guarded against by the evaporation being conducted in an iron vessel, or in contact with iron wire, which prevents the oxidation of that portion of the salt which is already formed. Carefully concentrated thus, the compound may be obtained, on cooling, in the state of a crystalline mass; but in this condition it cannot be long preserved, especially when air has contact with it, iodine being set free, as just indicated, and an oxide of iron mixed with iodide remaining. This salt is of no very great importance; it is sometimes employed in medicine, with other substances; it is also occasionally used as a photographic agent. Its symbol is Fe I, and the atomic weight, 154.

Iodide of Mercury.—Mercury is capable of forming several combinations with iodine, but that which will be noticed more particularly here, is the iodide or protiodide of the metal. If two equivalents of mercury and one of iodine are triturated together in a convenient vessel, moistening the whole with alcohol, a subiodide of mercury is obtained in the form of a greenish powder; the same compound is formed when a solution of subnitrate of mercury is precipitated with one of iodide of potassium. The resulting mass is composed according to the formula Hg₂ I.

If iodine be added to the solution of iodide of potassium, and the brownish liquid which results be mixed with a solution of subnitrate of mercury, a precipitate falls which differs in composition from the foregoing. It may also be procured by adding the iodide of potassium

to an acid solution of the mercurial salt, but the first is the surer method. It forms a yellow powder, which is apt to vary in its composition, according to the conditions in which the two salts are brought together. When treated with an acid, a red salt—the iodide—deposits. According to BOULLAY, this compound is composed of four equivalents of mercury and three of iodine, and is represented by the symbol Hg₄ I₃. The most remarkable of the mercurial compounds with iodine, owing to its fine scarlet hue, is that which is thrown down when dissolved chloride of mercury—corrosive sublimate, Hg Cl—is added to iodide of potassium. If the iodide of potassium has been added only sparingly, the tinge will be duller, in consequence of a portion of chloride of mercury being carried down; on addition of a further quantity of the reagent, however, this is displaced, and the whole of the quicksilver is converted into the brilliant-colored precipitate. The operator should guard against the opposite extreme of using too great an excess of the iodide, which would have the effect of redissolving it, and producing a soluble double iodide of mercury and of potassium.

The red iodide of mercury may likewise be obtained by triturating iodine and the metal together in the ratio of their equivalents, alcohol being added. This, however, should be done with only small portions at a time, for, when large quantities are operated upon, the temperature becomes so elevated as to volatilize much of the iodine. A duller-tinted compound is produced in this way, than that which results from precipitation with iodide of potassium or hydriodic acid.

When the iodide of mercury thus prepared is heated, it fuses, and a dark yellow mass remains, which, on solidifying, retains the yellow hue. As the temperature lowers, however, the original color is regained. The composition in both cases remains unaltered, consequently the dimorphous effect must be attributed to a molecular arrangement which is produced by the increased heat. Iodide of mercury is slightly soluble in water, alcohol, and ether, but hydrochloric acid, and various alkaline salts, dissolve it completely, producing soluble double salts with it. Its composition is—

	Centimally.	
1 Eq. of Mercury	100	44.25
1 Eq. of Iodine	126	55.75
1 Eq. of Iodide of mercury,	226	100.00

agreeing with the formula Hg I.

Iodide of mercury might be used as a pigment. It has been stated, by several French chemists, that its employment was contemplated some few years ago by English dyers and printers, for giving a bright color to cloths, but the Editor has not been able to learn anything of its application in this way.

Iodide of Silver.—This salt is easily prepared by adding to a solution of a soluble silver salt, an aqueous one of hydriodic acid, or of a soluble iodide. It forms a yellowish-white precipitate, which, when dried and heated, fuses to a reddish liquid mass, but changes to a dirty yellow.

The same salt is formed when iodine is made to act upon silver foil; or, according to M. ST. CLAIRE DE-

VILLE, when concentrated hydriodic acid is poured upon the metal, hydrogen being abundantly eliminated. It is found native, as specified in the beginning of this article. Iodide of silver is soluble in an excess of the alkaline iodide to some extent, but is only sparingly dissolved by water; it is not dissolved wholly by ammonia, like the chloride of this metal. In the presence of moisture, chlorine decomposes the iodide of silver, yielding a chloride of the metal and free iodine, which may be expelled by slightly raising the temperature. This reaction does not take place at a high temperature, as ascertained by M. ST. CLAIRE DEVILLE, but, in fact, hydriodic acid is capable of expelling hydrochloric acid from chloride of silver, and producing an iodide instead, contrary to the received opinion of the force of the affinity of these elements. He also found that on making a mixture of hydrochloric and hydriodic acids, and adding it to a solution of a soluble silver salt, only iodide of silver was produced. Chlorides of potassium and of sodium, dissolved in a small quantity of water, dissolve iodide of silver freely. Strong nitric and sulphuric acids are capable of liberating iodine from the iodide of silver, a nitrate or sulphate of the oxide of the metal being formed; this does not happen, however, when water is present, or the diluted acids are employed. Iodide of silver contains—

	Centum by
1 Eq. of Silver,	108 46.15
1 Eq. of Iodine,	127 53.85
1 Eq. of Iodide of silver,	235 100.00

consequently, its formula is Ag I .

The chief use which is made of this body is in Photography, and the various other systems in use for taking impressions of objects by the influence of light. As, however, in a future article this beautiful and very interesting art will be fully discussed, the action of light upon the salt in question will not be further pursued here.

Estimation of Iodine when uncombined and in combination.—The minute proportion of this element, which has often to be sought in plants, bituminous and other shales, waters, and even in the air, has taxed the inventive powers and researches of chemists for methods, of which the accuracy might be commensurate with the evident difficulty of the task undertaken. Fortunately, iodine comports itself with a few bodies in such a characteristic way, offering indications so marked as not to be surpassed in this respect by any other substance known. These are starch, silver, and palladium; and by proper modifications in the applications of only these three bodies, the methods for the estimation of iodine, as well when free as when combined, are not exceeded by any other class, either in their accuracy or extent.

Some of these methods are of recent invention, whilst others date from the first researches made upon this element by GAY-LUSSAC and others. Iodine in quantitative determinations is never weighed alone, but in combination with another body, with which it is chemically united—silver or palladium. These offer the greatest security for accurate results, since they produce compounds with the iodine which are unaffected by most

other substances. As a preliminary to the estimation either by silver or palladium, it is necessary to convert the iodine into hydriodic acid or into an alkaline iodide; and for this purpose a sample is weighed, and treated by any of the convenient methods already detailed for the production of hydriodic acid or iodides of the alkalies. If the iodine is mixed with potassa sparingly, and the brownish liquid treated with sulphide of hydrogen till it becomes colorless, iodide of potassium results; but in adopting this process, the last traces of the sulphide of hydrogen must be expelled, so as they may not interfere with the subsequent precipitation with nitrate of silver. A solution of the latter salt with a little nitric acid is then added as long as any precipitate is formed. By placing the beaker in a warm situation, the yellow iodide of silver falls, and the supernatant clear liquid may be decanted; the residue in the beaker may be washed either by adding water to it, agitating, and after it has subsided pouring off the clear solution, or it may be thrown upon a filter, washed thoroughly, and dried in the water-bath. The bulk of the precipitate is detached from the filter, and introduced into a porcelain crucible; the paper being burned on the lid at as low a temperature as possible, and the ashes added to the matter in the vessel. Subsequently, the whole is heated to a low red heat, and when cold, weighed. From the weight of the substance, minus that of the filter-ash, that of the iodine is calculated—234 parts of iodide of silver being equivalent to 126 parts of iodine.

In conducting this operation, it would be better to wash the precipitate by decantation, and afterwards to transfer it into the crucible, evaporating the water from the latter in the bath, and finally slightly heating over the lamp and weighing. No loss would be incurred in this by reduction of any part of the compound, as is done when a filter is employed. In either case, however, the results are very accurate. When a palladium salt is at hand, the mode introduced by LASSAIGNE is still better, and is now almost in every instance preferred to that just described. It is the more certain and convenient, as it offers a means of determining the iodine, even in the presence of chlorine and bromine, which the use of silver does not. The following is the method.—The liquid containing a weighed portion of the iodide under examination, or of the iodine converted into an iodide or hydriodic acid, is to be slightly acidulated with hydrochloric acid, and a solution of the protochloride of palladium added as long as a precipitate continues to form; the vessel is then placed in a warm situation for twenty-four or forty-eight hours, at the end of which time the clear liquid is passed through a filter, and the russet-black precipitate collected; it is washed with warm water, and subsequently dried till the weight remains constant, and the iodine calculated from the quantity of iodide of palladium thus found. As it is somewhat difficult and tedious to dry the precipitate when washed with water, it would be well to pour some alcohol upon the filter, after all the impurities have been first removed by the hot water, and after the spirit has passed through, to replace it with a little ether. When exposed to heat, the volatile liquid will readily escape, leaving the mass quite dry. FRESSENIUS

recommends to exsiccate the compound in vacuo over sulphuric acid. As the iodide of palladium is decomposed into iodine and metal by heat, the weight of the compound is taken after driving off all moisture by long exposure to a low temperature, or as above described; and as this is done in contact with the filter, the latter ought to be taken before collecting the salt, and after being exposed some hours to a heat of a water-bath. One hundred and seventy-nine parts of the dried salt—palladium 53 + iodine 126—contains one hundred and twenty-six of iodine. According to Rosé, the iodide after desiccation may be heated in the usual way in a platinum or porcelain crucible, and from the weight of the palladium which is left, the iodine calculated. LASAIGNE found that the $\frac{1}{400,000}$ th part of iodide of potassium could be determined in a liquid by this means, and the modifications, to which reference will be made presently, show that this is fully corroborated.

Upon the reaction of chloride of palladium with hydriodic acid or a soluble iodide, KERSTING has founded a volumetrical method of analysis for determining this element. He prepares for the purpose a number of test liquors with pure iodide of potassium and protochloride of palladium; the iodide of potassium solution is made of such a strength as to contain one part of iodine in a thousand of the liquid. This is done by dissolving 13.1 parts of the ignited salt in ten thousand parts of distilled water.

The palladium test liquor is prepared by dissolving one part of the metal in nitrohydrochloric acid with the aid of heat, evaporating the solution to dryness in a water-bath, and adding to the residue fifty parts of concentrated hydrochloric acid and two thousand parts of water, agitating the whole, and then allowing it to rest, to part with any insoluble matter. The value of this liquid is to be ascertained by adding to a given volume of it the iodide of potassium solution in successive portions, till the whole of the metal is thrown down. If the iodide test liquor be poured from a burette holding one thousand grains of water, and divided into one hundred divisions, the amount of palladium in the volume of solution operated upon may be readily ascertained from the number of measures of the other added, since each division contains exactly 0.1 grain of iodine, which is equivalent to 0.042 of palladium, since $126 : 0.1 :: 53 : 0.042$.

Having thus ascertained the quantity of materials in the two test liquors, the iodide to be examined is dissolved in water, if it admits of this treatment; a certain measure is then taken and operated upon qualitatively, as it were, in order to arrive at a knowledge of the probable quantity of iodine contained in it. For this purpose a number of measures of the palladium liquid is taken in a flask and heated in the water-bath; the measures of the liquid under examination are diluted till the ten make one hundred or a thousand grains. After the palladium solution is warmed, the other is dropped in from the burette in portions, taking care not to add too much at once, and also to shake the flask after each addition. The precipitate readily falls, and by drawing off, by means of a pipette, two portions of the liquid into two tall narrow foot-glasses, and adding to one a few drops from the burette and comparing

it with the other, it will be readily ascertained whether the whole of the palladium has been thrown down. If not, a further addition is to be made to the solution in the flask, to which the portions taken out for trial-tests must be put, and the whole left for a short time in the bath, heated as before from 140° to 212° , and as soon as the solid has settled to the bottom, a similar trial-test made. It is needless to say, that as the precise point is approached, the solution of iodide of potassium must be added more sparingly, and, when gained, the two liquids ought to be tested with the iodide of potassium and with the palladium liquor, using the former in one of the test-glasses, and the latter in the other. If no indication is obtained, it is proof that the whole of the palladium has been precipitated. Should, however, an excess of the iodide be added, the operator ought to introduce a few measures of the palladium test, and proceed more carefully in the precipitation till the desired point is attained. From the number of measures of the metallic solution operated upon, it is easy to ascertain the iodine, calculating from the data given in the preceding. A second test may now be performed, employing a given number of measures of the solution containing the iodine, and adding the other test solution till there is no further separation of iodide of palladium, in order to arrive at the true amount of iodine with greater certainty.

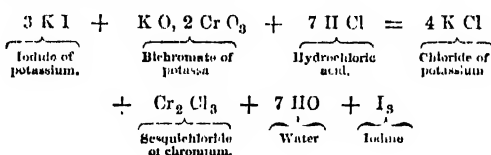
If the iodide under examination should be insoluble in water, or not well adapted for immediate solution, on account of admixture with foreign substances, it must be distilled from a small retort, with the neck turned upwards, with sulphuric acid, using for this purpose about twenty measures of the burette of strong acid, free from iodine, and from twenty to a hundred measures of water. The distillation must be continued till fumes of hydrated sulphuric acid begin to be evolved. Should the distillate contain free iodine and hydriodic acid, a few drops of starch paste, prepared by boiling one part of starch with one-tenth part of strong sulphuric acid in twenty-four of water, and then sulphurous acid, till the blue coloration occasioned by the free iodine and starch disappears, or is on the point of disappearing; on the other hand, if the substance distilled with the acid contains organic matter, causing, during the operation, an evolution of sulphurous acid, which condenses in the receiver, a few drops of the paste must be introduced, and then a solution of bleaching powder, till a faint bluish tinge begins to appear. This is an indication that the whole of the sulphurous acid has been converted into sulphuric acid; it is necessary, however, to destroy the azure tinge in the liquor by a few drops of solution of the sulphurous acid. After this, the testing with the palladium liquor is proceeded with in the manner detailed.

According to KERSTING, dilute hydrochloric, sulphuric, nitric, phosphoric, and acetic acids, and also the neutral salts of those acids with the alkalis, have no influence upon this method; neither have chloride of calcium or of zinc, acetate of lead, sugar, uric acid, and the distillate of urine with sulphuric acid, alcohol, ether, starch paste, oil of lemons, and bromide of sodium, in the presence of acetic acid. The test is interfered with, however, by the presence of alkaline

bromides with free mineral acids, especially upon heating; free alkalis, free chlorine, bromine, iodine, and cyanogen; large quantities of nitric acid at a high temperature, and sulphurous acid; for all these bodies prevent the precipitation of the iodide of palladium.

KERSTING has devised another mode, which is in application less complex than the foregoing, and affords, when none of those substances which interfere with the reaction are present, very trustworthy results. It is founded upon the behavior of chloride of mercury with a metallic iodide, tinged blue by the addition of a little starch paste and bromine water, in which case coloration is perceived as long as any of the iodide remains undecomposed by the mercurial salt, but by the decomposition of the last traces the blueness disappears. A test liquor, containing a certain known weight of chloride of mercury in a given volume of it, is prepared as in the preceding case, and the iodide to be examined is dissolved, and the liquor so diluted that it will contain about one part of iodine in a thousand, being previously blued by a little bromine water and starch paste, as previously mentioned. By adding the test liquor to this solution, iodide of mercury and chloride of the metal, in combination with the iodide, will be formed; but in consequence of the solutions being so diluted, the mercurial iodide dissolves, and so does not prevent the observation of the blue shade. When this disappears, the number of measures of test liquor required are read off, and from them the iodine is calculated. 135.5 parts of chloride of mercury are equivalent to 126 of iodine, and so in this proportion will any weight of the former salt in the solution added to destroy the color, be to its equivalent of iodine. When chlorides and bromides are present, also free mineral acids, acetic acid, and the acetates, the results afforded by this method are not exact.

Dr. FREDERICK PENNY has published a process for testing the quantity of iodine in iodides, volumetrically, by means of bichromate of potassa, which gives rise to the annexed reaction:—

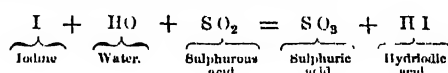


When heat is not applied, this is the only reaction which takes place, and by it three equivalents of iodine are set free by one of the bichromate of potassa. The manipulations are as follow:—Ten grains of pure bichromate of potassa are dissolved in about seventy measures of the burette, holding one thousand grains of water up to zero on the divided scale, and the remainder up to 0, filled with strong cold hydrochloric acid. The liquor is agitated and set aside. A weighed quantity of the salt to be examined is taken and dissolved in like manner in about a thousand grains of water, and to this the liquor from the burette is added cautiously till the whole of the iodine is precipitated. This is ascertained by letting a drop from the end of the glass-stirrer fall upon another of a freshly-prepared solution of protochloride of iron, mixed with sulpho-

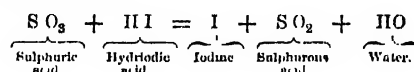
cyanide of potassium, and observing if a red coloration be produced. The bichromate solution is carefully added, stirring after each addition till this result is arrived at, and then the number of measures read off. Knowing that every ten divisions of the test solution contains one grain of the bichromate, and that their quantity effects the liberation of 2.437 grains of iodine from the sample, it is easy to estimate the weight of iodine in the quantity operated upon by the proportion:

$$10 : 2.437 :: x : y - \text{the iodine.}$$

Before leaving this part of the subject, which must be interesting to every chemical student, it may be well to lay BUNSEN's volumetrical method before the reader. It is founded on the behavior of sulphurous acid with iodine, which, in the presence of water, converts the iodine into hydriodic acid:—



This reaction is one among the many that the chemist and manufacturer encounter, and which at first sight appears inconsistent, since the converse can be effected as freely, namely:—



The state in which the substances are presented to one another has a great influence upon the nature of the change, and, consequently, demands careful study. In this case, the one or other of these reactions which result, is dependent upon the state of concentration of the materials which are taken to produce the effect. By careful experiments, BUNSEN found that the first reaction only is produced when a solution of sulphurous acid, containing 0.04 to 0.05 of real acid, is brought into contact with iodine; hence, when this condition is supplied, one equivalent of sulphurous acid is converted into sulphuric acid by an equivalent of iodine.

This comportment suggests, that when an unknown quantity of iodine is mixed with an excess of sulphurous acid of the above strength, by testing how much of the reagent remains in excess after the former substance has disappeared, the difference will afford data for calculating the quantity of iodine present. By means of a solution containing a known amount of iodine, the latter part of the reaction is performed.

Standard solutions of sulphurous acid, of the fore-mentioned strength, also one of iodine, one of iodide of potassium, and some starch paste, are required for performing the analysis by this method. The iodine test liquor is prepared by dissolving five grammes of the purest iodine in a concentrated solution of pure iodide of potassium, in a flask holding twenty thousand grains measure—twenty measures of burette—up to a certain mark, and diluting the liquor with distilled water till this mark is reached. A perfect homogeneity of the liquid should be effected by agitation, and care taken that it does not show any brown tinge. As each hundred divisions of the burette of this liquid contains 0.25—2000 : 5 :: 100 : 0.25—it is evident that

each division will contain a quantity of iodine equal to $\cdot 0025$ of a gramme. Lest impurities might be contained in it, it is necessary to subject it to a corroborative test to be certain of its value.

A sulphurous acid test liquor is prepared by saturating distilled water with sulphurous acid at the common temperature; this liquid should be kept in well-stoppered bottles inverted in water. From seventy to eighty divisions of this saturated liquor should be added to every hundred burette measures of distilled water.

The iodide of potassium test liquor is prepared by dissolving one part of pure iodide of potassium in ten parts water; it should form a colorless liquid, and give no tinge even on the addition of hydrochloric acid.

It is necessary to prepare the starch paste fresh for each testing. Before proceeding to operate upon samples of unknown composition, it is requisite to find the relative proportion between the iodine and sulphurous acid solutions; and also what quantity of the respective agents is present in a given volume of them. To effect this, it is required, in the first instance, to measure off two burette measures, that is, two hundred burette divisions of the diluted sulphurous acid solution, and add thereto six or eight divisions of starch paste; then a solution of the iodine is dropped in from the burette, and the flask agitated till there is a slight excess of the iodine, and the starch acquires in consequence a persistent blue color.

Operating in this way, and supposing that, to convert the two hundred divisions of sulphurous acid into sulphuric, one hundred and eight of the iodine liquor were required, it is evident that these numbers will stand in the same relation to one another when the iodine is to be determined, as when it is wished to estimate the sulphurous acid. The next step is to find how much pure iodine is contained in each degree or burette division of the iodine test solution, and likewise its effect upon the sulphurous acid. This is done by weighing off $0\cdot 40$ gramme of dry and pure bichromate of potassa, and treating it in a small retort with concentrated hydrochloric acid, and conducting the evolved chlorine into a solution of iodide of potassium. For this end the bichromate and acid are put into a flask, to which a tubulure and tube are adapted, and secured by passing a tube of caoutchouc over the neck, cork, and portion of the tube; a small glass bulb, with its long neck closed by the blowpipe, is put into the end of the education tube, and then introduced into an inverted retort, containing the solution of iodide of potassium. Heat is applied by means of a lamp, and, after a few minutes' ebullition of the contents of the flask, the whole of the chlorine will have passed over. There will be liberated from the iodide of potassium, by the chlorine evolved from the quantity of bichromate operated upon, $1\cdot 024$ of iodine—that is, an amount proportionate to three equivalents of iodine for one of the former salt, as stated at page 400. To the solution containing the mixture of iodine and iodide of potassium, the diluted sulphurous acid liquid must be added from the burette till the brown color of the fluid has completely disappeared, and the quantity is noted, which, for example's sake, may be taken at sixteen hundred divisions. It is needless to say that there has

been an excess of the acid employed on this occasion, and which is to be determined in the next operation, by introducing a little starch paste, and as much of the standard iodine solution as is requisite to communicate a blue color to the fluid. If for this purpose twenty divisions of the burette are taken, from the following calculation, founded upon the preceding tests, the value of the solution as to the iodine it contains, and the sulphurous acid it changes into sulphuric, is arrived at. As by the previous experiment it was found that fifty-four divisions of the iodised solution were necessary to oxidise two hundred of the sulphurous acid liquor, it follows that four hundred and thirty-two of the former will be required to oxidise the one thousand six hundred measures taken of the latter; but, as the experiment shows that the iodine liberated from the iodide of potassium is equivalent to this volume of test liquor, minus the twenty divisions required for the excess—that is, $432 - 20 = 412$ divisions, corresponding to $1\cdot 024$ of iodine—it is evident that each burette division of the iodised test liquor contains $\cdot 00248$ of a gramme of iodine. Of course, each degree of the entire quantity of the test liquor possesses this value.

To test the iodine in a sample submitted, a portion is to be weighed off in a flask, and dissolved in iodide of potassium of the strength specified in the foregoing, using about ten divisions of the burette for each one-tenth of a gramme of the iodine. The dilute sulphurous acid liquor must now be added in measured quantities from the burette, till all color in the solution disappears; the quantity thus used is noted; a few divisions of starch paste are stirred with the menstruum, and the iodine test liquor carefully dropped in, stirring well after each addition till the blue iodide of starch appears. The volume of sulphurous acid and the number of divisions of the iodised test liquor which are required to oxidise the excess of the acid above what was necessary to convert the iodine in the sample to hydriodic acid being known, it is easy to find, by the following mode of calculation, the proportion of iodine in the sample. Thus, supposing that a thousand divisions of the acid solution were taken in the first instance, and that to oxidise the excess which remained of this, ten divisions of the iodine liquor were required, it follows that the weight of the sample taken, supposing it a gramme, contained $0\cdot 6448$ of iodine, and, consequently, $64\cdot 48$ per cent.; for, as found by the foregoing experiments, fifty-four divisions of the iodine liquor were equivalent to the oxidation of two hundred of the sulphurous one; hence $200 : 54 :: 1000 : 270$, and $270 - 10 = 260 \times \cdot 00248$ —the amount of iodine in each division—gives $0\cdot 6448$, as stated.

For the detection of the grosser adulterations of iodine, which are mentioned as being practised, although they have not come within the range of the Editor's experience—such as plumbago, sulphide of antimony, and the like—a rough estimate may be formed of the amount, by heating a weighed sample of iodine in a porcelain crucible to redness, till the whole of this element is volatilized, and weighing the fixed residue. This, though not so precise as those other methods which have been detailed, does not require that accu-

racy of manipulation which is presupposed to be possessed in the other instances.

When small quantities of iodine have to be found—as, for instance, in the ashes of plants, the residuary matter left after the evaporation of spring or river waters, and the like—the methods by which they are to be detected must evidently insure all possible accuracy, if the investigator is anxious to arrive at the truth. For a long time the tests known, such as decomposition of the iodide by sulphuric acid, and addition of starch paste, were found insufficient to determine the minute traces of iodine which, as appears by late researches, are contained in several bodies. Without entering upon the general description of all the tests proposed, a few of the more remarkable may be briefly noticed.

At the head of investigations of this kind stands the test of PRICE, detailed in the Transactions of the Chemical Society for 1851. It consists in operating upon the solution which is supposed to contain the iodide with hydrochloric acid and starch paste, and then adding a few drops of a solution of nitrite of potassa, when a blue coloration from the iodide of starch makes its appearance. The hydrochloric acid liberates the iodine from its basic combination, and is retained in the liquid in the form of hydriodic acid; this body is decomposed by the nitrite, the acid of which is set free by the excess of hydrochloric acid—the hydrogen being converted to water, and the iodine liberated. When much iodide is present, the color of the liquid is dark blue, and appears immediately; but when only a small quantity is contained in the substance operated upon, the shade is lighter, and a few seconds elapse before its appearance. This chemist states that he has detected iodine in a solution containing not more than the four-millionth part of it, and that there is no difficulty in ascertaining the presence of iodine in cod-liver oil, and in the mother-liquor from a few pounds of sea-water, by its aid.

M. GRANGE's method is analogous to that just described, only that he directs the transmission of a few bubbles of fuming hyponitric acid through the solution to be tested, and already impregnated with starch paste; the reaction is instantaneous; and when the iodine forms about the five-millionth part of the fluid, a pale rose color, inclining to violet, is produced. With a larger proportion, say the one three hundred thousandth, this chemist asserts that the characteristic blue appeared; but when only the one-millionth of iodine is present, he states that no satisfactory results can be attained by this test *per se*. Coupling it, however, with another method published by RABOURDIN, founded upon the property of chloroform, of dissolving iodine, and becoming reddish-coloured thereby, it can be rendered so accurate as to satisfy the minutest inquiry. Should a portion of the fluid afford no indication with starch paste and hyponitric acid, the latter is to be transmitted through the bulk of the solution at hand, till it manifests an acid reaction; a small quantity of chloroform is agitated with it, and then drawn off with a pipette; the reddish color is removed by the addition of a little potassa, and the aqueous solution then decanted. The hyponitric test is then applied, when it does not fail to produce the characteristic blue color.

In this way, the one-five millionth of iodine is easily detected. GRANGE found that bromides do not interfere with the accuracy of these reactions, for they are not decomposed by the hyponitric acid.

M. MORIDE has proposed a substitute for the chloroform in the preceding method, which offers advantages in giving a solution which is more highly colored than the chloroform becomes under similar circumstances. According to this chemist, wherever iodine is indicated by starch paste, it may be proved also by the employment of benzine more satisfactorily. This agent is rendered more valuable from the fact, that the water which is present, or which may be used to wash it, carries away any bromine or chlorine, thus leaving the iodine isolated.

Chlorine, though capable of setting iodine free from its combinations in aqueous solutions, is now rarely employed to detect iodine, since an excess of the agent converts the iodine into a colorless combination of chloride of this element. Bromine comports itself differently, for although it is capable of liberating it, still none of the iodine is redissolved. DE LUCCA has made this behavior the basis of a method for the analysis of iodides by means of a standard solution of bromide, coupled with the use of sulphide of carbon, which takes up the iodine as it is liberated by the bromine liquor. From the volume of the latter which is expended in setting free the whole of the iodine—ascertained by the sulphide of carbon being colorless when drawn off with the pipette—its quantity is found.

To show that iodine is contained in the air, *et cetera*, modifications of the processes above described have been successfully employed by CRATIN, PERAPATH, and others; but to enter into further details upon this subject, although highly interesting, appears unnecessary.

IRON.—*Fer*, French; *Eisen*, German; *Ferrum*, Latin.—Iron is a metal of a bluish-grey color, but acquiring a brilliant surface by polishing; its fracture is fibrous, and it is the hardest and toughest of all the ductile metals; it cannot be hammered into very thin plates, but may be rolled into thin sheets, and drawn into very fine wire.

The iron of commerce is seldom or never pure, containing small portions of carbon, sulphur, silicon, phosphorus, arsenic, *et cetera*; its density varies a little according to its purity and the mode of its manufacture. Purified by fusion with smithy scales, it gave in some experiments a specific gravity of 7.8439, which is increased by rolling and drawing into wire. Pure soft bar-iron, containing only a trace of carbon, has a density of 7.79; that of ordinary bar-iron is 7.788.

When iron is subjected to a red heat, it softens and becomes tough, a circumstance which adds much to its value in the manufacturing arts; and its property of welding at a white heat, gives a facility in working it which no other metal possesses. When heated above the welding point, it crumbles under the strokes of the hammer.

The melting point of iron has been variously given as 1550° C.—*Pouillet*; 1587°—*Daniell*; 6346° C. or 175° Wedgwood—*Morveau*; 158° Wedgwood—*Mackenzie*. Any impurity in the metal makes it more easily fused,

and might account for small discrepancies in the melting point; but the remarkable differences shown in the above results enable us to appreciate the great difficulty of obtaining accurate measurements of very high temperatures.

Iron is attracted by the magnet, and is itself easily rendered magnetic, but does not retain this property except when converted into steel.

HISTORICAL NOTICE.—Iron, wherever known, has universally taken the lead amongst the metals in point of usefulness, and its possession by any people has invariably proved the means of advancing them in the arts of civilized life, and of raising them in the scale of nations. It is strange that, notwithstanding the difficulties in its manufacture, iron is amongst the first metals mentioned in history. MOSES tells us that TUBALCAIN, the great-grandson of CAIN, ADAM's son, was an instructor of every artificer in brass and iron, that iron furnaces were in use in ancient Egypt, and that the hills of Palestine produced ferruginous ores. JOB says,—Iron is taken out of the earth;—and throughout the whole sacred volume this metal is referred to as being in common use, both for weapons of war and manufacturing instruments.

HOMER mentions a mass of iron as one of the prizes at the funeral games given by ACHILLES in honor of PATROCLUS, a circumstance showing the great value attached to it in ancient times, when it was so much less common than at the present day:—

Then hurl'd the hero, thundering on the ground,
A mass of iron—an enormous round—
Whose weight and size the circling Greeks admire,
Rude from the furnace, and but shaped by fire.

Who furthest hurls it takes it as his prize.
If he be one enriched with large domain
Of downs for flocks, and arable for grain,
Small stock of iron needs that man provide;
His hinds and swains whole years shall be supplied
From hence; nor ask the neighboring city's aid
For ploughshares, wheels, and all the rural trade.

There are also notices in HOMER and HESIOD of the methods of reducing and forging iron; but cast-iron was then unknown, an imperfectly malleable iron being produced at once from the ores in the furnace. It is conjectured that the Greeks obtained most of their iron through the Phœnicians, from the shores of the Black Sea and of Laconia. DIODORUS SICULUS refers to the Island of Elba as yielding ores of iron, which the natives were accustomed to dig and cut out of the ground, subsequently melting the mass to obtain the metal. PLINY in his Natural History enters at great length upon the manufacture of iron; he says the ores are to be found almost in every country, and that they are easily discovered by the color of the earth which breedeth the iron, and that they are tried by fire like other veins of metal. He speaks of it also as being applied to all the uses for which it is commonly employed in the present day. It is remarkable, however, that although in all the Latin writers, *ferrum*, iron, is the most common name for a sword, the weapons and cutting instruments discovered in the ruins of Pompeii and Herculaneum are almost invariably found to be made of bronze.

The furnaces which were first employed for smelting

iron were probably simple conical structures, with small openings below for the admission of air, and a large one above for the escape of the products of combustion, erected on high grounds that the wind might assist combustion. Similar rude furnaces, known as *air-bloomeries*, are still used in some countries at the present day. Successive layers of ore and charcoal being placed over the fire, the heat would be regulated by opening and closing the apertures. Subsequently, an artificial blast would be introduced, and the advantages of this appear to have been known at a very early period; for HOMER represents HEPHÆSTUS as throwing the materials from which the shield of ACHILLES was to be forged, into a furnace urged by twenty pair of bellows. This blast-bloomery would ultimately be developed into the *catalan forge*, in which malleable iron is produced directly from the ore by heating it in contact with carbon—a process still adopted in some places where wood is abundant for making charcoal, as in the Pyrenees, in Corsica, and some parts of Spain. Finally, it assumed the form of the *blast-furnace*, now in general use, and which, by completely fusing the ore in contact with the fuel, results in producing cast-iron—a compound of the pure metal with carbon.

The transformation of the blast-bloomery into the blast-furnace is supposed to have taken place in the early part of the sixteenth century; for proof exists that in the seventeenth the art of casting had arrived at considerable perfection. The more efficient operation of the blast-furnace allowed the reduction of the heaps of scoria, which had been gradually accumulating during the period that the blast bloomeries had been in operation. In the Forest of Dean in Monmouthshire, in Yorkshire, and other counties, these were found in immense beds, among which were discovered Roman coins and other specimens, inscribed to the god who presided over iron. There is ample evidence of the industry of the Romans in working the iron mines of Britain, until their final abandonment of the island about A.D. 409. It is supposed, also, that the Danes, during their occupation of England, carried on the smelting of iron extensively, and hence many of the heaps above-mentioned are called in certain localities *Danes' cinders*. A portion, only, of the ore was reduced by the imperfect methods of smelting then known; and, in the Dean Forest alone, it is computed that twenty furnaces, for a period of nearly two hundred years, were supplied chiefly with the bloomery cinders as a substitute for iron ore.

Up to the beginning of the seventeenth century, charcoal was the only material employed in smelting operations. An enterprising ironmaster in Worcestershire, named DUDLEY, was the first who attempted the operation with pit-coal, and the trial was so successful, that about the year 1620 he applied for a patent for his invention, which was granted for thirty-one years. For some time he succeeded in producing considerable supplies of iron, which could be sold with good profit at a much reduced price; but this very success was the cause of his ruin, by exciting the animosity of his rivals, from whom he encountered incessant opposition, and, by combinations among masters and men, he was ultimately turned out of his works. With DUDLEY

died for a time the art of making iron with pit-coal; but the rapid destruction of the forests, not only to supply the great consumption of the blast furnaces, but also the wants of a constantly increasing population, induced at length special enactments prohibiting the cutting down of timber for the use of the ironworks. The first effect of this prohibition was greatly to reduce the number of furnaces; so much so, that in 1740 the annual production, which had previously amounted to one hundred and eighty thousand tons, was diminished to seventeen thousand three hundred and fifty tons.

The change from charcoal to coke as fuel necessitated a more powerful blast, and a longer subjection of the materials to the heat. The latter was effected by an enlargement of the height of the furnace, and the former by the introduction of large cylinders, with closely fitting pistons, instead of the common forge-bellows. The earliest blowing cylinders of any magnitude are supposed to have been those erected by SMEATON at the Carron Ironworks in 1760. These improvements speedily effected an astonishing increase in the production of iron. About the year 1780, the furnaces still worked with charcoal produced only eleven tons of iron weekly, while those in which coke and coal were used averaged a weekly product of seventeen and a half tons. Dr. URE gives the quantity of cast-iron produced in 1788 as follows:—

	Tons
By means of coal.....	42,800
By means of charcoal.....	13,100
Constituting a total quantity, ..	61,900

In 1796 the wood-charcoal process was all but entirely given up, and the gross produce of one hundred and twenty-one blast furnaces was one hundred and twenty-four thousand eight hundred and seventy-nine tons, being near to twenty tons weekly for each furnace; and in ten years after this, 1806, there were two hundred and twenty-seven blast furnaces in this country, one hundred and fifty-nine of which were in active blast at once, and produced two hundred and fifty thousand tons of iron.

The blast furnaces were distributed as follows:—

In the principality of Wales.....	52
In Staffordshire.....	42
In Shropshire.....	42
In Derbyshire.....	17
In Yorkshire.....	28
In the counties of Gloucester, Monmouth, Leicester, Lancaster, Cumberland, and Northumberland.....	18
Scotland,	28

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Nearly simultaneous with the earliest improvements in the manufacture of cast-iron by means of pit-coal, were others of an equally important kind for converting the cast-iron into malleable or bar-iron. Hitherto this had been effected by means of wood charcoal in what are termed refiners, as is still practised in the South of France; but owing to the scarcity of wood fuel in this country, the charcoal was mixed up with coke for the refining operation; the iron produced from this was hard and of an inferior quality, and much time was required for the conversion of a ton of cast into malle-

able iron. England was therefore greatly indebted to Sweden and Russia for iron of good quality, and not less than seventy thousand tons annually were imported from these countries. In 1783, Mr. RICHARD CORT, after many trials, succeeded in converting cast-iron into malleable iron, by the use of pit-coal in a reverberatory, instead of a blast furnace, and thus introduced what is known as the *puddling process*. For some time much difficulty was experienced in puddling, from the loss of iron, and irregularity in the quality of the metal produced and the fuel used. To avoid this, the iron was subjected for a short period to a process of refining with the blast and coke fuel, previous to being transferred to the puddling operations in the reverberatory furnace. The original puddling furnace, patented by Mr. CORT in 1784, says MUSHET, is now, *without the intervention of the refining*, producing tens of thousands of railway bars all over the world. This invention placed England in an independent position as respects iron, and so facilitated the manufacture of malleable metal, that before many years one work could turn out annually as much bar-iron as was made previously by the whole iron trade of the kingdom. Notwithstanding the value of these improvements, Mr. CORT did not benefit by his inventions. After spending thousands in experimenting, and giving to the world his results, those who were the gainers repudiated his claims while they adopted his processes, leaving him to drag out the rest of his days in poverty; and it was only in the course of last year that the Government granted a small acknowledgment of fifty pounds per year to the widow of the great benefactor of his country, while the children and grandchildren have been appealing to the sympathy and charity of the ironmasters, for what they should have received through their father as a right.

The general introduction of the steam-engine, as improved by WATT, contributed also to initiate a new era in the history of the iron trade, as in almost every branch of industry. Its application to pumping enabled the mines to be sunk to a greater depth, and accelerated the process of raising the coal and ores; by employing it as the motive power for urging the blast, refractory ores were reduced with facility, and the processes of rolling, forging, *et cetera*, were now effected with a rapidity previously unknown.

Lastly, the discovery of the hot-blast process, for which a patent was taken by Mr. NEILSON of Glasgow in 1824, and by which three or four times the quantity of iron can be produced with little more than one-third of the fuel that was required with the cold-blast, effected another complete revolution in the iron trade, and may be regarded as marking the last era in the history of this all-important metal. The high expectations at first formed from BESSEMER'S new and markable refining process, of which an account will be given, have not yet been realized.

SOURCES.—In admirable harmony with the universal application and innumerable uses of iron, is its almost universal presence in nature. It is by far the most widely diffused of all the metals; there being few substances in the material world that do not contain it in greater or less amount; and yet the variety

of ores from which the metal is manufactured is very limited.

Native Iron.—For a long time native iron was unknown, and its existence in nature questioned; it has been found, however, in several localities both on the Continent of Europe and in America. In this country it has been met with in minute quantity in trap rocks, but on all occasions it is found only in small portions, and is considered more in the light of a chemical or mineralogical curiosity than as a useful source of the metal. Native iron is almost pure white, more resembling silver than ordinary iron, is generally softer and less dense, and, unlike meteoric iron, contains no nickel. A mass was found with magnetite at Grass Ramsdorf, not far from Saalfeld in Thuringia, which, according to KLAPROTH, consisted of:—

	Centesimally
Iron,	92.5
Lead,	6.0
Copper,	1.5
	100.0

It is said, however, to be found in considerable quantity in Liberia. The natives use it for instruments; it is soft and flexible, and can be easily cut with a chisel. An analysis of this gave:—

Iron,	98.87	98.40
Silica,	1.63	1.60
	100.00	100.00

This is the purest yet described from any locality. In 1786, a mass of native iron, weighing upwards of thirteen tons, was found in South America, a sample of which was sent to the British Museum. It is described as being soft and compact, although the internal part of the mass is full of cavities; it had every appearance of having been in a fused state, and was considered the product of a volcanic irruption. No analysis of this sample has been made.

Small quantities of native iron have been obtained in the immediate vicinity of a coal seam which had been spontaneously ignited, and was doubtless the result of reduction by the coal; samples of this sort are excessively hard and fine-grained, and give a fracture resembling cast-steel, from which circumstance it has been named *native steel* or *steely iron*. A mass of this mineral, weighing sixteen pounds six ounces, was discovered some years since near Nexy, in the department of the Allier.

Meteoric Iron.—Large masses of metallic iron have been discovered from time to time, in different parts of the globe, embedded in the soil and also lying upon the surface; others of a similar kind have been known to fall from the atmosphere, and are hence termed meteorites. These masses are generally covered over with a kind of black enamel, which protects the metal from the action of the atmosphere. The iron forms usually a sort of network round a crystallized metallic mineral of a complicated composition. These meteoric masses are sometimes so large, and the metal which they contain so pure, as to furnish the inhabitants of the neighborhood with ample material for knives and spearheads. When examined chemically, there seems

a considerable similarity in the composition of different specimens, although some of them contain ingredients which others do not. In the following table this similarity is very apparent, although the samples were obtained from localities widely apart:—

No	Iron.	Nickel	Cobalt.	Copper and tin.	Manganese	Phosphorus.
1	92.47	5.67	0.23	—	—	—
2	93.77	3.81	0.21	—	—	—
3	88.01	10.73	0.45	0.66	0.13	—
4	88.23	8.52	0.76	—	—	—
5	66.56	24.70	—	—	—	—
6	83.57	12.66	—	—	—	—
7	89.78	8.88	6.67	—	—	—
8	85.61	12.27	0.89	—	—	—
9	90.88	8.45	0.66	—	—	—
10	88.98	10.35	—	0.56	—	0.11
11	85.00	13.01	1.42	0.57	—	—
12	86.64	13.04	—	0.27	—	0.05

These are but a few of many analyses that have been given, all showing a remarkable sameness in composition. Besides these ingredients, the meteoric mass is sometimes found to contain silica, alumina, lime, potassa, chromium, magnesia, soda, arsenic, carbon, sulphur, chlorine, *et cetera*.

Protoxide of Iron.—This oxide has never been found in nature except in combination with other matters, forming distinct minerals. Its great tendency to combine with more oxygen, obtained either from the air or other substances, prevents it existing as protoxide for any length of time, unless it is entirely excluded from the presence of oxygen. This compound may be prepared by precipitating a solution of protosulphate of iron, by a caustic alkali, and carefully filtering; but it is impossible to obtain it in the dry state by this method, from its affinity for oxygen. It may be said that protoxide of iron does not exist in a separate state in nature; its composition is—

	Centesimally.
Oxygen,	8
Iron,	27
	35
	100.00

Magnetic Oxide of Iron.—When the protoxide combines with more oxygen, it does not pass at once into the highest state of oxidation, but into a mixture of protoxide and sesquioxide, which is permanent and magnetic, and is hence termed magnetic oxide. This compound, when found as a mineral, has a black color, and is hard. It exists abundantly in nature in different rocks; in granite, mica-slate, clay-slate, syenite, hornblende, chlorite, and also in some of the limestone formations. Much of it is found in the Island of Elba, and it has been obtained from that island for making iron from the earliest times. It also abounds in the United States of America; and mostly all the Swedish iron is manufactured from the magnetic oxide. This ore occurs in crystallines, of which the primitive is a cube: its general forms are the octahedron and dodecahedron. Its density varies from 5.00 to 5.10; it fuses before the blowpipe with difficulty. In powder it is perfectly soluble in warm hydrochloric acid. Its chemical composition is—

8 Eqs. iron,.....	81	Centesimally.	71.68
4 Eqs. oxygen,.....	32		28.32

1 Eq. magnetic oxide,.. 118 100.00

corresponding to the formula Fe_3O_4 or $\text{Fe}_2\text{O}_3 + \text{FeO}$. The last is considered to be the true formula, expressing a combination of one equivalent of sesquioxide and one of protoxide. The analyses obtained of magnetic oxide of iron give—

Iron,.....	71.86	71.91
Oxygen,.....	28.14	28.09
	100.00	100.00

Specular Iron Ore—Red Hematite.—This is a sesquioxide of iron existing in great abundance, and found in a variety of shapes, both massive and in crystals. The following are a few of the crystalline forms in which it is found—Figs. 272, 273, 274. The crystals are of

Fig. 272.

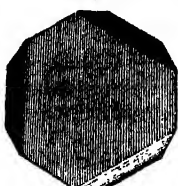


Fig. 273.

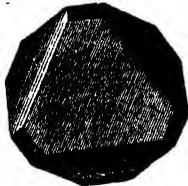


Fig. 274.



a dark steel-grey color, but leave a reddish-brown streak upon a stone or any hard substance; they have a specific gravity varying from 4.8 to 5.3; and are a pure sesquioxide, composed as follows:—

2 Eqs. iron,.....	54	Centesimally.	69.34
3 Eqs. oxygen,.....	24		30.66
	78		100.00

This same oxide exists in a variety of other forms, such as a fibrous mass, with the fibres radiating from a centre, in which state it is termed the *red hematite* or *fibrous iron ore*. When the ore is an amorphous mass, it is termed *compact iron ore*; when mixed with clay and other earthy matters, *red ochre*; when hard, and combined with silica, *jaspery ore*; when in scales of a black metallic lustre, it is known as *micaceous iron ore* or *iron glance*.

This ore occurs both in the primitive and secondary rock; it abounds in the Island of Elba, Norway, Sweden, and Switzerland. Fine specimens are met with in the fissures of rocks in the volcanic districts. The red hematite, found in masses, having an unctuous feel, and readily soiling the fingers and everything with which it comes into contact, exists in many parts of England, particularly in Cornwall and Ulverston. This variety has generally from eight to ten per cent. of

silica. It is wrought in great quantities along with poorer kinds of iron, and produces a strong metal. When subjected to a high heat alone, such as the jet of the blowpipe, it yields a portion of its oxygen, and is converted into the magnetic oxide. It is very slowly soluble in hydrochloric acid. The following are several analyses of this ore from different localities:—

Iron,.....	70.42	70.27	69.85	69.22	69.	68.96
Oxygen,..	29.58	29.73	30.15	30.78	31.	31.04
	100.00	100.00	100.00	100.00	100.	100.00

Another form of the same oxide, in combination with water, is very abundant as a mineral known as *brown iron ore*. It has a brownish color, produces a yellow streak, and, when crushed, a yellow powder; it is thus easily distinguished from the anhydrous oxide, which yields a red-brown powder. It is of lower specific gravity than the red, varying in density from 3.8 to 4.2. It usually occurs in a massive state, and is composed of—

4 Eqs. iron....	108	Centesimally.	59.0
6 Eqs. oxygen...	48		26.3
3 Eqs. water,.....	27		14.7
	183		100.0

This corresponds to the formula which is always given for the ore, $2\text{Fe}_2\text{O}_3 + 3\text{H}_2\text{O}$. The following are the results of three analyses:—

Peroxide of iron,..	80.25	90.53	86.34
Water,.....	15.00	9.47	11.66
Silica,.....	3.75	—	2.00
Loss,.....	1.00	—	—
	100.00	100.00	100.00

Brown iron ore is found both in amorphous masses, and in crystals of a variety of forms, according as the ore may have been produced either by the decomposition of iron pyrites, or substitution and oxidation of carbonate of iron. It also occurs in small rounded pieces, either loose or conglomerated, in which state it is known as *pea iron ore*. When mixed with clay and other earthy matters, and of a soft texture, in which state it is found in great beds, it is termed *yellow ochre*. It exists in great quantities in Normandy, Berry, Lorraine, Burgundy, and constitutes the principal supply of ore for many of the French ironworks.

BOG IRON ORE.—This ore is amorphous, having a vitreous lustre, yellowish and dark-brown in color; it is of very recent formation, and is produced from the decomposition of certain rocks over which water passes; it is therefore always found in low marshy places, and hence its name. The following are the results of analyses of this ore from different localities:—

Sesquioxide of iron,.....	78.57	43.4	66.0	66.33	51.0	70.05
Protoxide of iron,.....	—	—	—	3.60	—	—
Lime and magnesia,.....	—	—	—	—	—	2.43
Oxide of manganese,.....	—	15.0	1.5	0.75	—	1.78
Phosphoric acid,.....	—	—	8.0	0.12	10.99	0.84
Water and organic matters,.....	21.43	15.0	23.0	26.40	28.80	15.87
Silica,.....	—	23.0	—	2.80	9.20	8.03
Alumina,.....	—	3.2	—	—	0.41	1.50
	100.00	99.6	98.5	100.00	100.40	100.00

IRON PYRITES.—The affinity between iron and sulphur is equal to that between iron and oxygen, varying according to the circumstances in which they are placed; under one condition, oxygen will take the iron from the sulphur, and again, under other circumstances, iron will leave the oxygen for the sulphur. That these conditions may have determined the different combinations in nature is a probable hypothesis. Sulphur and iron are combined in a great variety of proportions, and give rise to an important series of minerals, the most abundant being what is termed iron pyrites or bisulphide of iron. This mineral varies in tint, according to its exposure, from a yellow bronze to a silver white; the high bronze yellow hue may be familiar to every one in what is termed the sulphur in coal, which is iron pyrites; it has a metallic lustre, and is very hard, being capable of striking fire with steel, and therefore occasionally termed firestone; it is very brittle, and has a specific gravity of from 4·8 to 5·1. It occurs in beautiful cubical and octahedral crystals, some of which are represented by the following figures.

Different localities are known to give pyrites with a certain definite form of crystal peculiar to each, as for

Fig 276.

Fig 276

Fig. 277.



instance, the Island of Elba, which yields pyrites in crystals extremely large, and often of a pentagonal dodecahedron form, while some of the Cornish mines abound more in cubical crystals. A familiar instance of this form is seen in the common slate, and is popularly termed, *slate diamond*; these are true cubes of iron pyrites. The composition of this mineral is:—

		Per cent
1 Eq. of iron,	27	45·76
2 Eqs. of sulphur,	32	54·24
	59	100·00

expressed by the formula Fe S_2 .

The various analyses of this mineral have given a composition which exhibits the following relations to the theoretical numbers above indicated:—

Iron,	47·85	46·08	46·53	46·5
Sulphur,	52·15	53·92	53·39	53·5
	100·00	100·00	99·92	100·0

Pyrites is very widely diffused through rocks. It has not yet been used as a source of supply for the manufacture of iron, but is most extensively employed for the making of sulphuric acid and alum—see Vol. I., p. 156. The residue of the heaps in making acid or alum is a sesquioxide of iron, with some remaining sulphur and earths, and is used as a coarse pigment for out-door purposes, under the name of *colcothar* or *purple brown*.

There is a certain kind of pyrites very common

in the mineral districts, and found in round and sometimes curiously-shaped nodules in clay, which when broken has a radiated appearance of fibres proceeding from the centre, or sometimes from various centres, and is often either compact or granular. This sort is termed *white pyrites*, it being lighter in the color. It is also termed *cockscomb pyrites*, from its radiations. It has a density varying from 4·69 to 4·90. When analysed it is found to have the same composition as the other sort, but is much more liable to spontaneous decomposition. When exposed to a damp atmosphere, it often crumbles to pieces; the sulphur is oxidised and converted into sulphuric acid, which combines with the iron to form sulphate of iron or copperas, and appears as an efflorescence of minute crystals on the surface of the mineral. This sort of pyrites is very plentiful in Anglesea and several of the copper mines of this country. White iron pyrites is more liable to be impure than the ordinary kind, and when found in mines of other metallic ores, it is often impregnated with some of the other metals. That of Anglesea often contains both copper and zinc, and frequently small portions of silicious and argillaceous matter. A specimen analysed by BERZELIUS gave:—

Iron,	45·07
Sulphur,	53·35
Manganese,	·70
Silica,	·80
Loss,	·08
	100·00

Magnetic Iron Pyrites.—This is a sulphide distinct from the common pyrites. It is found mostly in masses filling up fissures of rocks, is seldom crystallized, and is not very abundant. Occasionally it is met with associated with common pyrites, but is distinguished from the latter by being of a deeper color, and also, as its name implies, magnetic. It has a density of 4·6, and is composed of—

		Centimally
7 Eqs. of iron,	189	59·63
8 Eqs. of sulphur,	128	40·37
	317	100·00

represented by the formula, $\text{Fe S}_2 + 6 (\text{Fe S})$, which expresses a combination of bi- and proto-sulphide of iron.

The following are several analyses of this mineral which agree with the formula—

Iron,	59·29	56·38	59·61	59·72	59·8
Sulphur,	40·71	43·62	40·43	40·32	40·2
	100·00	100·00	100·04	100·04	100·0

Another iron pyrites is also found, which differs little from the common, except in the form of crystal; generally, however, it has a little of another matter in it, which is present more as an impurity than as forming a part of its constitution. This mineral is known as *marcasite*, and its composition by analyses is—

Iron,	45·60	45·60	45·68
Sulphur,	53·05	53·05	54·34
Manganese,	0·70	—	—
Copper,	—	1·41	—
Arsenic,	—	0·93	—
Silica,	0·80	—	—
Loss,	0·08	—	—
	100·00	100·99	100·00

ARSENICAL IRON PYRITES—Mispickel.—This mineral is met with abundantly in Cornwall and upon the Continent. It is often associated with other metals, as tin. It is found in crystals, but more generally as an amorphous mass. It has a grey, silver-white color and metallic lustre, is very hard, and has a specific gravity of from 5·7 to 6·2. It is easily known from the strong smell of garlic it emits when struck by the hammer or rubbed on anything hard or heated. It is a combination of sulphur, iron, and arsenic, and is composed of—

		Centesimally
2 Eqs. of Iron,	54 ..	33·54
2 Eqs. of Sulphur, ..	32 ..	19·87
1 Eq. of Arsenic,	75 ..	46·59
	161	100·00

agreeing with the formula $\text{Fe S}_2 + \text{Fe As}$.

Another variety of arsenical pyrites is known under the technical name *Dunaite*, differing from the above in having cobalt as a constituent. Its analysis from different localities does not vary much, as the following two examples show:—

Iron,	26·54	33·28
Cobalt,	8·31	6·52
Sulphur,	17·57	18·02
Arsenic,	47·55	41·86
Loss,	0·3	·32
	100·00	100·00

Besides the few which have been described, there are several other sulphides of iron well known to mineralogists, either from their peculiar form of crystal or the state in which they are found combined. There are likewise a great variety of other minerals, being combinations of iron with other metals, as cobalt, nickel, *et cetera*; also with other matters, forming arseniates, silicates, and the like, some of which will be noticed in another part of this article. Amongst these may be specified copper pyrites, composed of copper, iron, and sulphur, but which is never wrought for the iron it contains, although yielding more of it than the ore which is generally worked for that metal.

CARBONATE OF IRON.—This is the most common ore of this country, from which the greater part of the iron is manufactured, and of which there are several varieties. The true carbonate, or *spathose iron ore*, often occurs crystalline, generally in well-shaped six-sided prisms, and rhombohedrons, similar to carbonate of lime; although more generally the ore is obtained in a massive state, with a foliated structure. It is mostly of a light-brown or grey color, having a pearly lustre, varies in specific gravity from 3·0 to 3·85, and is composed of—

		Centesimally
1 Eq. protoxide iron,	35 ..	61·4
1 Eq. carbonic acid,	22 ..	38·6
	57	100·0

It is, therefore, represented by the formula Fe O, CO_2 .

This mineral, however, often contains small portions of manganese and earthy matters, as the following analyses of samples from different localities will show:—

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Oxide of iron, ..	53·06	49·61	59·63
Carbonic acid, ..	38·41	38·44	38·04
Manganese,	4·20	0·10	1·89
Magnesia,	2·26	5·18	—
Lime,	1·12	6·67	1·20
Silica,	0·48	—	—
Loss,	·47	—	—
	100·00	100·00	100·76

The most of the ores from which British iron is made consist of a carbonate found in beds in the coal formation, often alternating with the seams from which the coal is taken. This circumstance gives great facility to the manufacture of iron in this country, and is at once the cause of the superiority and cheapness of the metal. The great deposits of this kind of iron ore in Britain are those of Dudley in England, those of Wales, and of Lanarkshire and Ayrshire in Scotland. These ores are always massive, and generally contain several impurities, which, if not extracted, affect more or less the quality of the iron. They may be divided into two sorts:—

The first is the argillaceous or *clay-band* ores which contain a considerable quantity of earthy matter or clay, and these, when wrought by themselves, yield a weak and inferior quality of iron. They have a dark-grey color, nearly black, and a specific gravity varying from 3·17 to 3·41. The following analyses give a fair average of their composition taken from different districts:—

Protoxide of iron, ..	32·22	38·80	35·0
Carbonic acid, ..	32·53	30·76	25·5
Manganese, ..	—	0·07	0·3
Lime,	8·62	5·30	—
Magnesia, ..	5·19	6·70	1·6
Silica, ..	9·56	10·87	20·5
Alumina, ..	5·34	6·20	11·6
Sesquioxide of iron, ..	1·16	0·33	—
Carbon, ..	2·13	1·87	—
Sulphur, ..	0·62	0·16	—
Loss,	2·63	—	—
	100·00	101·06	100·7*

Black-band.—The second variety of this kind of ore, which is known as *black-band*, was for a long time unknown, and was first pointed out by the late D. MURPHY. It differs from the clay-band in having less earthy matters, and being much blacker in color. Some kinds of this ore have a homogeneous appearance, while others have coal seams running between, and round light-brownish matter, stratified or in nodules; the whole mass or seam of this sort being of a mixed brown and black. The following analyses of a few samples of black-band exhibits the difference between it and the clay-band or argillaceous carbonate:—

Protoxide of iron, ..	49·4	49·6	46·6
Carbonic acid, ..	35·2	30·4	30·1
Magnesia, ..	4·0	8·1	—
Alumina, ..	1·8	1·8	—
Lime, ..	—	—	6·3
Silica, ..	—	—	5·4
Coaly matter, ..	9·6	9·6	8·4
Loss, ..	—	0·5	3·2
	100·0	100·0	100·0

This class of ore is exceedingly valuable to the manufacturer, as the presence of the coal assists in some of the preliminary operations. These two ores, the

black and clay band, are generally wrought together, and give iron of excellent quality.

A most valuable addition to our knowledge of the iron ores of the Northern and North Midland Counties of England has been recently given to the world, in the *Memoirs of the Geological Survey of Great Britain*. These are to be further extended, and the completion

of the work will be hailed as a great boon by chemists and iron manufacturers. At the same time, unless these analyses of the ores be followed up by a similar investigation into the flux and fuel used, and the iron produced from the ores, the directors of the Museum of Practical Geology will only tantalise the manufacturers by an unfinished work:—

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
Sesquioxide of iron,	49.57	—	95.16	90.55	86.50	94.23	1.77	1.45	2.39	1.69	1.30
Protoxide of iron,	10.77	49.47	—	—	—	—	35.38	36.14	41.77	39.38	39.87
Protoxide of manganese,	3.06	2.12	0.24	0.10	0.21	.23	.94	1.31	1.13	.95	1.38
Silica,	6.64	4.91	5.66	7.05	6.18	4.90	19.13	17.37	8.93	12.16	13.50
Alumina, . . . . .	.84	.06	.06	1.43	.50	.63	7.63	6.74	4.79	6.42	6.13
Lime,	5.69	3.47	.07	.71	2.77	.05	3.35	2.70	2.55	2.26	2.12
Magnesia,	1.21	3.15	—	.06	1.46	trace	2.33	2.17	3.85	3.89	2.77
Carbonic acid,	14.49	37.71	—	—	2.96	—	25.41	26.57	31.39	29.38	28.17
Phosphoric acid, . . . . .	.01	trace	trace	trace	trace	trace	.48	.34	.75	.47	.69
Sulphuric acid,	trace	trace	trace	trace	.11	.09	trace	trace	trace	trace	trace
Bisulphide of iron, . . . . .	.03	.08	trace	.06	—	.03	.18	.10	trace	trace	.05
Water,	8.44	—	—	—	—	.56	1.85	1.77	1.70	2.09	1.80
Organic matter,	trace	trace	—	—	—	—	.23	2.40	.86	.54	.83
Potassa, . . . . .	.05	—	—	—	—	—	.78	.65	.43	.37	.18
	100.80	100.29	100.19	99.86	100.49	100.50	93.46	99.71	100.34	98.80	99.09

	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.	XX.	XAI.
Sesquioxide of iron, . . . . .	.79	1.49	2.18	2.16	1.17	1.42	2.30	2.69	3.49	3.60
Protoxide of iron,	33.72	37.99	35.71	33.56	38.97	28.27	40.01	33.11	39.75	39.92
Protoxide of manganese,	1.01	1.51	1.23	.96	1.09	1.02	1.26	2.18	1.50	.95
Silica,	16.02	10.04	16.06	17.13	11.90	3.55	11.19	17.21	10.22	8.62
Alumina,	6.41	5.57	7.09	8.19	5.93	2.31	5.91	8.85	5.65	7.06
Lime,	3.99	4.59	3.01	3.17	1.62	13.94	2.78	2.32	3.38	7.41
Magnesia,	5.49	3.37	2.96	3.06	4.82	9.27	2.85	2.11	2.88	3.82
Carbonic acid,	28.14	29.92	26.74	25.63	30.14	37.61	29.72	21.83	28.63	22.85
Phosphoric acid, . . . . .	.41	.80	.66	.75	.18	.74	.34	.62	1.12	1.86
Sulphuric acid,	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace
Bisulphide of iron, . . . . .	.13	.06	.05	.26	.05	.04	.09	.11	.05	.11
Water,	1.14	2.21	2.17	2.25	1.63	.90	1.57	2.57	1.75	2.97
Organic matter, . . . . .	.36	1.12	.76	1.57	.30	.92	1.38	1.85	1.14	trace
Potassa, . . . . .	.47	.55	.66	.71	.67	.16	.31	.49	.68	.27
Titanic acid,	—	—	—	—	—	—	—	—	—	.03
	98.88	99.52	99.31	99.77	99.10	100.15	99.74	99.52	99.84	100.37

OVERMANN has the following remarks on the clay-band of America:—

The compact carbonate of iron, sphaeroiderite, argillaceous iron ore, has no relation externally with the sparry variety; it comprehends most of the clay ironstones of the coal measures, particularly those which occur in flattened spheroidal masses, varying in size from the dimensions of a small bean to pieces weighing a ton. The color of this ore is commonly a dirty blue or grey-brown, reddish-brown, and yellowish-brown; fracture close-grained, hard, streaked white or brown, blackens before the blowpipe, and if calcined, is attracted by the magnet. This carbonate of iron, though belonging to the coal formation, is found in various places in the tertiary strata. It is the principal ore from which iron is smelted in England and Scotland, and yields usually from thirty to thirty-three per cent. of iron. It is largely distributed over the United States—Pennsylvania abounds in it. It exists in Maryland, Virginia, Ohio, Illinois, North Carolina, and Kentucky. The difficulty of working this kind of ore in the blast furnace, may be assigned as the reason why it is not more generally employed. England and Scotland use it extensively, and work scarcely any other kind.

VALUATION OF IRON ORES.—The value of the ore depends upon two conditions:—first, the quantity of iron it contains, and, second, the amount of impurities or matrix. The character and properties of the impurities, and the extent to which they will interfere with the quality of the iron when manufactured, must also be considered. To ascertain these points, the ore must be subjected to testing or assaying. There are two methods of assaying, termed respectively the wet and dry.

Wet Method.—What is termed the wet assay is the most accurate, and may be performed by any ordinary operative, after a short experience. Although, in the first instance, the operator wishes only to ascertain the quantity of iron in the ore, still, that being only a part of the process for obtaining the whole of the ingredients, it will be better to describe here the complete analysis required for practical purposes. The mineral being ground, weigh fifty grains and put them into a flask or ~~beaker~~ add pretty strong aqua regia, and then digest the whole on a sand-bath at a boiling heat for fifteen or twenty minutes; remove the vessel from the heat, and add a little water; after allowing it to stand several minutes, decant the clear

solution; add to the undissolved residue as much acid and water as at first, and repeat the digestion; then put the two solutions together, pour the whole into a porcelain basin, and evaporate to dryness; next add two ounces hydrochloric acid, and two ounces water, digest for ten minutes, and pour the whole upon a paper filter, taking care not to lose any of the liquid; wash the residue upon the filter till the liquor passing through is free of acid; dry the filter, heat the contents in a crucible to redness, and then weigh. This gives the insoluble matter. The filtrate is now carefully divided into two equal proportions; to the one is added caustic ammonia in excess, and then filtered; the contents of the filter are well washed, and then dried; the liquid filtered through with the washing is to be kept. To the other half of the solution add caustic potassa till the iron is precipitated, then add a considerable excess, and boil the whole for ten minutes, filter while hot, and wash the precipitate with warm water till the alkali is all removed; the iron precipitate is then dried. These two iron precipitates are now heated to redness in a crucible, and weighed separately; the weight of the one obtained by potassa will be that of the sesquioxide of iron; the weight of the other will be the sesquioxide of iron and alumina, if any of that substance has been dissolved; the difference of weight will therefore indicate the alumina, which is noted down. The quantity of iron which the sesquioxide contains is known by calculating their equivalents, which are as ten to seven:—thus, if the sesquioxide obtained be 12.5 grains, then $10 : 7 :: 12.5 : 8.75$, and this being in twenty-five grains, will make the percentage of the ore thirty-five.

To the solution filtered from the precipitate by ammonia, there is added oxalate of ammonia, so long as a precipitate is formed, if there be any; this is stirred well, and after heating the solution it is again filtered, and the precipitate washed and dried. This is the lime in the state of oxalate, which is converted into carbonate of lime by subjecting it to red heat in a crucible, and then weighed. As the carbonate is the condition in which the lime would exist in the mineral, no calculation is required. To the solution filtered from the lime is added a little solution of phosphate of soda; the mixture is well-stirred for seven or ten minutes, and then allowed to stand for an hour; if a precipitate is formed, it is filtered, well washed, dried, and burned at a red heat; this precipitate is the phosphate of magnesia. When burned and washed, the quantity of magnesia present in the mineral is known from the fact, that every 237 parts of the precipitate are equal to 85.4 magnesia.

When the ore is to be tested for sulphur, it is better to take a separate portion of the mineral—say twenty-five grains—and digest in two parts hydrochloric and one nitric acid, for half an hour, then dilute and filter, and add to the filtered solution chloride of barium—allow it to stand for an hour; any precipitate formed is sulphate of baryta, which is obtained by filtering, washing, and then drying and burning; every one hundred and sixteen parts of this precipitate is equal to sixteen parts of sulphur. If only the quantity of iron be required, then the operator need go no further than the first

precipitate, but he will have to take potassa only, and proceed as directed above.

The preceding method is applicable to any of the ordinary classes of iron ore, such as the hematite, brown oxide, magnetic, *et cetera*. Sulphides are never used for the manufacture of the metal; but even these, such as the common pyrites, may also be tested in the same way.

A few years ago Professor FUCHS recommended, for ascertaining the value of iron ores, the following process, founded upon the fact that copper reduces sesquioxide of iron to the state of protoxide:—Take fifty grains of the powdered ore to be operated upon, and digest in strong hydrochloric acid till all the iron is dissolved—say about half an hour; then add by degrees about twenty-five grains of chlorate of potassa to oxidise the iron—neither nitric acid nor nitrate must be used for this purpose. When the iron is oxidised, the solution is brought to boil, then a clean slip of pure copper is added, which must have been previously weighed, and the solution is kept in ebullition to prevent access of air. After ten minutes' boiling, and previous to removing the undissolved copper from the solution, hot water is to be added till the vessel is quite full; this is to be poured off, and the vessel again filled with fresh hot water. The copper, which is generally covered with a brownish coating, is then carefully washed in cold water, dried at a gentle heat, and finally weighed; every four grains of copper dissolved indicates five grains of sesquioxide of iron present in solution; the quantity of metallic iron may then be calculated as already stated.

The advantages of a process of this kind are not only that it is simple and easy to perform, but the presence of any of the earthy matters, as silica, lime, alumina, or other metals, does not interfere with it; only, if the ore contains arsenic, this process will not answer. Much care must be taken not to prolong the operation, as copper is dissolved by the acid present in small quantity, and in that case the results cannot be relied on; yet many are able from experience to perform the analysis in this way with great accuracy.

Another simple process for testing the quantity of iron in an ore, based upon the reaction of the protosalts of iron upon permanganate of potassa, has been proposed by MARGUERITE:—When a solution of permanganate of potassa is poured into a very dilute acid solution of protosalt of iron, the protosalt becomes converted into the sesquioxide at the expense of the oxygen of the permanganate, decoloring the solution. As long as any protosalt of iron remains, it is immediately decomposed in proportion as the solution of the permanganate is gradually poured into it, the liquor assuming a very pale yellow color, due to the sesquioxide of iron produced; but as soon as all the iron is oxidised, one single drop of permanganate suffices to impart a distinct pink color to the liquor, which indicates that the experiment is finished.

Permanganate of potassa is prepared as follows:—

	Parts
Binoxide of manganese,	2
Chlorate of potassa,	1
Caustic potassa,	3

Mix the whole thoroughly, introduce the mixture into

a Hessian crucible, and keep it at a low red heat for about two hours. The mass, which is of a dark-green color, is then reduced to coarse powder, and mixed with three or four times its weight of water; after stirring the whole, nitric acid, diluted with half its weight of water, is gradually added until the liquor assumes a fine violet color; it is then filtered through pounded glass or asbestos, and preserved in a glass-stoppered phial. The reason of filtering through asbestos or glass is because contact with organic matter, such as paper or linen, decomposes the permanganate. The salt is very stable, and may be preserved for a long time without alteration, provided always that it be kept in a glass-stoppered bottle, and contact with dust or any organic matter carefully avoided.

To make the permanganate of the proper strength, dissolve twenty-five grains of pianoforte wire—which may be considered pure iron—in about 1500 grains by measure of pure hydrochloric acid. When dissolved, and the disengagement of hydrogen gas has ceased, dilute the solution with about one pint and a half of water. It is necessary to dilute the solution to this extent, and to operate in the cold, in order to guard against the excess of hydrochloric acid reacting upon the permanganate and disengaging chlorine; one thousand grains-measure of the solution of permanganate of potassa, prepared as before described, being introduced into an alkalimeter, it must now be gradually poured therefrom carefully, drop by drop, into the hydrochloric acid solution of iron just alluded to, stirring the liquor all the time in order to insure complete action, exactly as in alkalimetry.

On adding the solution of permanganate of potassa, the operator will perceive that, at first, it is decolorized as fast as it is poured in; but the rapidity of action gradually diminishes, and, at last, it imparts to the liquor a pinkish tint, which indicates that the whole of the iron in the liquor is oxidized. The number of divisions which have been required to obtain that result is carefully observed; and supposing, for example, that fifty divisions of the alkalimeter have been required to oxidize the twenty-five grains of pianoforte-wire employed, it is evident that each division of the permanganate of potassa test-liquors represents half a grain of metallic iron.

But whatever may be the strength of the solution of permanganate, it is always easy to adjust it to any desired standard; if too weak, by concentrating it by evaporation at a gentle heat; if too strong, by diluting it with a suitable quantity of water, so that it may be brought as near as possible to such a strength that one measure of the alkalimeter may indicate half a grain of metallic iron.

Take twenty grains of the iron ore and reduce them to very fine powder by levigation; put them into a flask capable of holding about a quart of water, and pour into it about one thousand grains-measure of pure and fuming hydrochloric acid. The mixture is now moderately boiled until the ore has dissolved. Water is then poured in, so as to fill up about one-third of the flask; and the salt of iron is brought entirely to the state of protosalt, by adding about one hundred grains of pure zinc, or about sixty grains of sulphate

of soda. After boiling for a few minutes, and as soon as the liquor no longer evolves an odor of sulphurous acid, and has become greenish or almost colorless, all the iron has passed into the state of protosalt. The solution is then diluted with a fresh quantity of water, so as almost to fill the flask, and the test-liquor of the permanganate of potassa is poured in, drop by drop, until the characteristic pink color is produced. The operator then reads off the number of divisions employed.

Let it be supposed, for example, that the test-liquor is of such a strength that each division represents half a grain of pure iron, and that twenty-two divisions have been required to oxidize the metal contained in the twenty grains of ore operated upon. It is evident that these twenty grains contain eleven grains, and consequently fifty-five per cent. of iron.

This process is obviously much more rapid than any of those previously described, and the presence of any other metal or earth does not interfere with the results—except two, namely, arsenic and copper. Should either of these be present, they may be separated, previous to applying the test, by a bar of zinc, which precipitates them. Then filter the solution, and proceed as described.

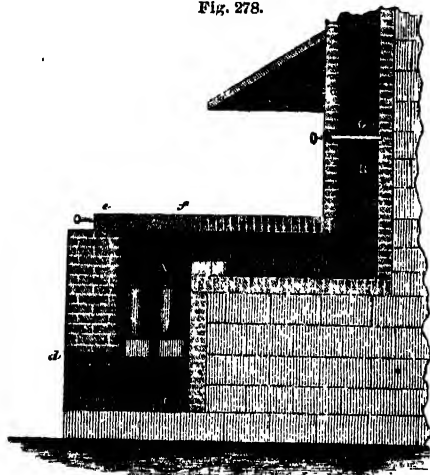
The Dry Method.—By the preceding methods, it will be observed that it is the quantity of pure metal that is estimated; whereas, by the process of smelting, the metal is not obtained pure. Some metallurgists prefer using a process more analogous to the smelting operations for testing the value of the ore and the quality of the iron, and for this purpose practise what is termed the dry assay; this is performed by taking a sample of the ore and fusing it in a crucible, to obtain the iron in the metallic state. It will have been observed, that the ores generally contain small portions of silica, alumina, *et cetera*. Such matters are by themselves infusible; but at a high temperature they combine with the oxide of iron, and form a fusible compound; so that were the ore put into a crucible alone and fused, iron would not be obtained, but a combination of oxide of iron. It is necessary, therefore, to mix with the ore some matters that will combine with the substances named, and set the iron free. Such are termed fluxes and reducing agents; but even by the aid of these, the operation of assaying by the former requires great care, and necessarily a very high heat, the apparatus and operations for which are as follow.

The common assay furnace is of a very simple form. It is generally constructed upon the floor of the room, close to where there is a chimney, so as to insure a good draught. The following sectional sketch—Fig. 278—will give the best idea of its construction. A is the fire-place containing two crucibles; B, the chimney; C, ashpit open from the front for the admission of air; D, the grate bars; E, F, cover for fire; G, damper for regulating heat.

The grate bars are loose pieces of bar-iron half an inch square, leaving an intervening space of the same size, and laid loose, so that they may be removed and the fire-place cleaned out, as the coals and bricks are apt to cake and choke up the fire-place. The latter should be lined with the best fire-brick built in with fire-clay,

and should be from sixteen to eighteen inches square, and from twenty-four to thirty inches deep. The fire is fed from the top, which is covered by a fire-clay

Fig. 278.



tile, furnished with a rim of iron. The whole furnace should be strapped round with belts of iron, to prevent its splitting or falling to pieces by the expansion; or a very common method, and the most secure, is to fit them round with a cast-iron casing, which is a great preventive against the furnace rending and admitting currents of air. The most suitable fuel is a mixture of coal and coke. The furnace should be at a good heat before the crucibles are put into it. Some assayers place a small piece of tile or brick upon the bars on which the crucibles stand, while others embed them in the fire, which is the best method for obtaining an equal heat round the crucible. In a furnace of the size stated, two or three crucibles may be placed in the fire at a time, and this is often recommended; but the Editor prefers to use only one at a time, as giving the most certain results, though requiring a little longer for the operation. The most refractory kind of crucibles should be used; those termed the Cornish and Hessian answer very well. A good assortment of them, laid in a warm place, should be kept on hand by the assayer. Covers are also prepared for them, by baking a piece of fire-clay into the required shape and size.

For the purpose of inserting or removing the crucibles from the furnace, a number of different-shaped tongs are wanted. There are also required the following fluxes and reagents—pounded charcoal, slaked lime, potassa and soda, tartar, borax, and ground glass. If the assayer has a knowledge of chemical operations, he will, before making an assay, ascertain by means of tests, as already referred to, an approximate idea of the quantity of lime, silica, and alumina present, so as to regulate his fluxes; but it often happens that the assayer is ignorant of this, and he consequently judges of the quality of the ore and the fluxes to be used by the appearance of the ore when ground and burned. The assay is then proceeded with, by first taking a sample of the ore and grinding it fine in an iron mortar, weighing out two hundred grains, and placing it, mixed with an equal quantity of dry slaked lime and fifty grains of powdered char-

coal, upon a clean piece of glazed paper; but if the ore be a refractory one, a little carbonate of soda or potassa may also be added.

The crucible should be previously prepared by filling it with pounded charcoal, moistened with water; this should be pressed into the crucible, and dried. A hole is scooped out in the centre of the charcoal, so as to leave about one quarter of an inch of charcoal all round. The mixed ore and flux are put into this cavity; the crucible is covered and luted with clay, and then placed in the centre of the furnace, the fire of which should have been allowed to burn low. When the crucible is properly embedded, coal and coke are packed all round and over it, filling the furnace nearly to the top; the crucible being as nearly as possible in the centre of the fire. For a time the fire is allowed to burn slowly, so as to drive off all damp from the ore and crucible. After a while the fire is covered, and the heat raised to the highest pitch and continued for about half an hour, when the cover of the furnace is removed, and a portion of the fire is taken out from the top, to expose the crucible, which is then withdrawn by a pair of tongs, giving it a gentle tap upon the floor, to shake down any particles of fused metal. When cool, the lid is taken off and the contents examined. For this purpose the crucible is generally broken; if the temperature has been sufficient, a small button of metallic iron will be found under the slag; if the heat has not been high enough, or a proper supply of flux has been wanting, the slag is full of small metallic beads, or the whole forms an agglutinated mass; in the latter case, the only remedy is to repeat the operation. If the process is successful, the small button of iron is carefully detached and hammered, to drive off any scoria adhering. The success of the whole operation is judged of by the appearance of the slag; it should be a greenish or greyish glass. This should be ground fine and spread upon paper, and a magnet drawn over it to detect any little prill of iron which may have remained in the slag. The whole iron is then weighed and the per-centage calculated. Iron thus obtained is not perfectly pure, but in general it is as pure as cast-iron, and may therefore be taken as the true valuation, if cast-iron is to be made from the same ore.

MUSKET, in his work upon iron and steel, enters extensively into the assaying of different ores by the furnace; he arranges the ores for assay into three classes—*argillaceous*, *calcareous*, and *silicious*—according to the earthy matters that prevail, so that there may be a proper distribution of flux, and each class is divided into two varieties, as follows:—

	First variety	Average proportion.	Second variety	Average proportion.
<i>Argillaceous iron ore</i> ,	Clay, ..	9	Clay, ..	10
	Lime, ..	6	Silica, ..	7
	Silica, ..	3	Lime, ..	3
		18		20

For every four ounces troy of this class of ore, he recommends as flux the following ingredients well mixed:—

	First variety	Second variety.
	Ounces.	Ounces.
Bottle-glass,	4	4
Chalk,	3	4
Charcoal,	0.50	0.75

Second class of ores:—

	First variety.	Average proportion	Second variety	Average proportion
<i>Calcareous iron ore,</i>	Lime,.....	14 ..	Lime, ..	10
	Clay,	6 ..	Silica, ..	6
	Silica,	4 ..	Clay,	4
		24		20

The flux recommended for this class is—

	First variety. Ounces	Second variety Ounces
Bottle-glass,	5	4
Chalk,	1.50	2
Charcoal,	0.75	0.50

Third class of iron ores is:—

	First variety.	Average proportion.	Second variety	Average proportion
<i>Silicious iron ore,</i>	Silica,	12 ..	Silica,	10
	Lime,	8 ..	Clay,	7
	Clay,	5 ..	Lime,	5
		25		22

Flux recommended for four ounces of ore:—

	First variety. Ounces.	Second variety. Ounces.
Bottle-glass,	3.50	3.50
Chalk,	3	2.50
Charcoal,	0.75	0.50

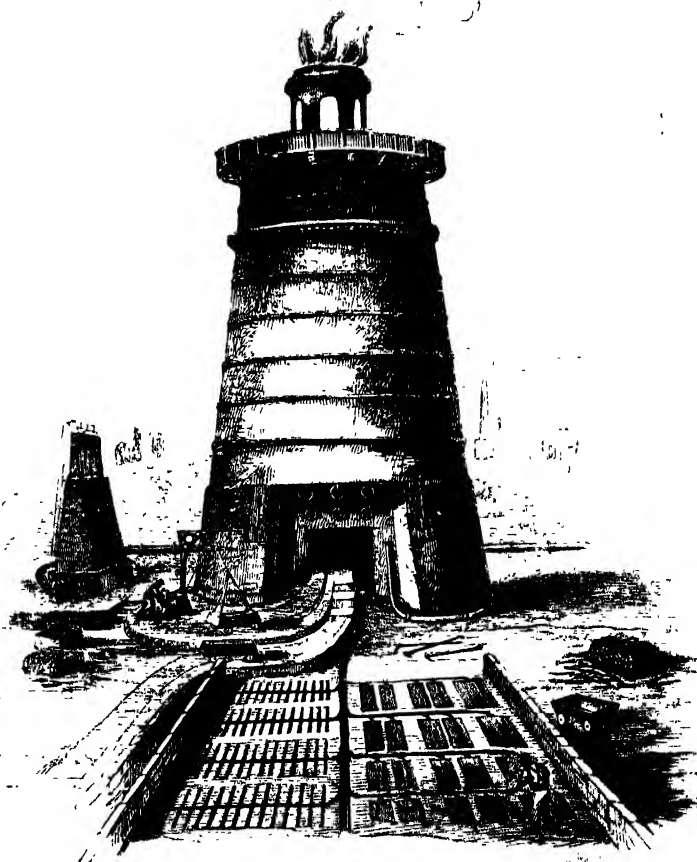
For hematite and such like ores that contain small portions of silica, the best flux for four ounces is—

	Ounces.
Chalk,	1.50 to 2.
Charcoal,	0.50

Many assayers use slaked lime alone; others add with the lime small portions of the alkaline carbonates, or borax, which often facilitate the fusion, especially with such ores as contain much silica and alumina, and are, consequently, very refractory.

The button of iron obtained in the assay is subjected to the following test:—It is placed between a fold of thin tin-plate, to prevent it flying away on being struck, it is then hammered upon an anvil and broken; if the button flattens before breaking, and the fracture have a greyish appearance, the quality is considered good;

Fig. 279.



but should it split on the first blow of the hammer, and show a crystalline fracture, whitish in appearance, it is not good, and the ore is judged unfit for the best quality of iron.

MANUFACTURING OPERATIONS.—Iron is produced for the purposes of the arts in three different states—as *crude* or *cast-iron*, *steel*, and *malleable* or *bar-iron*. These three modifications are the results of several and separate operations, undertaken for the express purpose of obtaining the quality of iron desired; although, when each is tested separately, they are found to differ only in the quantity of carbon or charcoal in their composition. Malleable iron is the purest, and has very little carbon in it; to have it quite pure is the aim of the manufacturer, but this is never accomplished in practice. Steel contains more carbon than bar iron, and cast-iron generally more than steel; but there is no fixed proportion of that ingredient in either by which a line may be drawn between them; they seem to merge into one another, so that some kinds of steel may be called cast-iron, and some cast-iron may be considered steel. The difference is often more dependent upon the mode in which the carbon is combined with the iron, than on the exact quantity present. Ordinary crude or cast-iron contains, also, other impurities, as silica, which render it very inferior; and the variable amount of silica and carbon found in different kinds, gives rise to a great variety of qualities of cast-iron, distinguished by technical names, such as *grey*, *mottled*, *white*, *silver*, *et cetera*.

The manufacturing operations succeed each other in the following order:—1. The calcination of the ores, by which the carbonaceous and volatile matters are burned off, and the whole reduced in bulk to prepare them for the smelting furnace; 2. The extraction or reduction of the metal in the form of cast-iron by smelting; 3. The conversion of the cast-iron into malleable or wrought iron by puddling and rolling; and 4. The reconversion of the comparatively pure malleable iron into that particular carbide which is known as steel.

CALCINATION OF THE ORES.—The carbonated ores of this country are generally prepared for the blast furnace by a process of calcination which burns away all volatile matters, and concentrates the metal. For this purpose the ores are accumulated in large heaps, generally in an open field, and mixed with carbonaceous matters, such as small coal. Some of the black bands have sufficient coal in their composition to effect their calcination. After a heap of several hundred tons is collected, a fire is kindled at the windward end, which gradually passes on through the whole mass and burns for several days, producing a very high heat, often sufficient to reduce and fuse some of the metal, which, however, is not desirable.

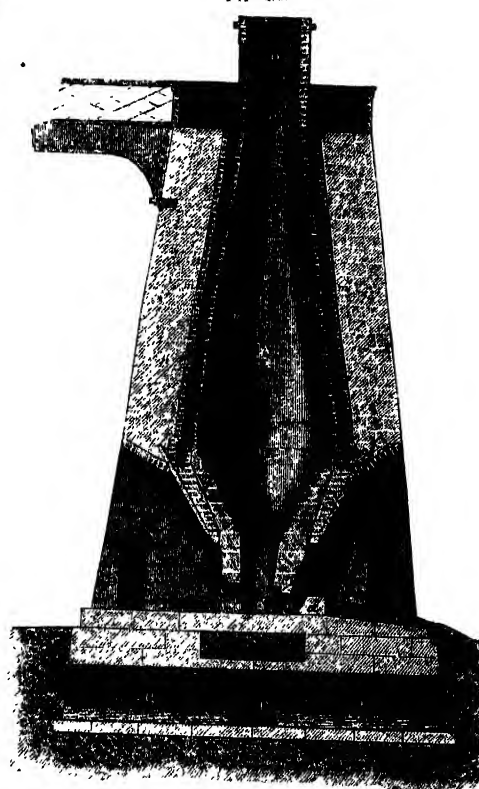
The black-band iron ore, of the average of thirty-three per cent. of iron, will contain, after calcination, an average of seventy per cent. of iron. The clay-band of thirty per cent. of metal in the ore, will, when properly calcined, contain about fifty-four per cent., so that by this means a great saving is effected in the amount of fuel required for the subsequent operation of smelting.

Instead of roasting the ore in open heaps, the same operation is sometimes performed in kilns, similar to those used for burning lime. In some districts, this method is found more convenient than large open heaps, covering often several hundred square yards.

SMELTING THE ORES.—The next operation is the smelting or reduction of the calcined ore, and the first subject which falls to be considered under this head is the form and *materiel* of the furnace.

The structure of the blast furnace varies considerably in different localities, according to the views of the smelter and the character of the ore and fuel, but in their general features there is much sameness. Drawings will be given of a few of the forms adopted at different times and in different places; but to enable the reader to understand the references to particular parts, it may be well to introduce, in the first place, an external and sectional view of a blast furnace of modern construction. The former is shown in Fig. 279, including the sand-bed in which the metal flows, to form the pigs of cast-iron as they are taken to market. Fig. 280 is a section of a similar furnace, consisting of two courses of fire-brick, *m m m*; between these is a

Fig. 280



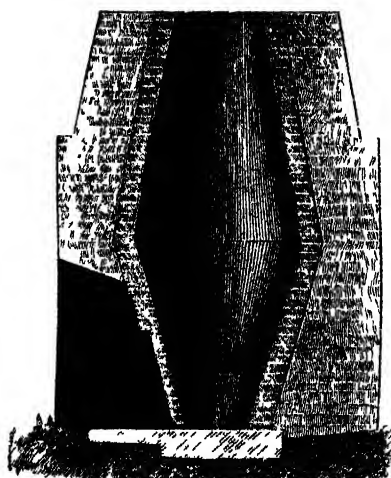
casing, *U*, of pieces of brick, scoria, and sand. Over the whole is the external coating of thick masonry, *n n*, formed either of ordinary bricks or of stone, as is most convenient. The inside lining of fire-bricks is technically termed the shirt of the furnace; the part extending from the cross line at *n*, and running down into the crucible portion at *E*, is composed of fire-stone; occasionally fire-bricks of the most refractory sort are used for this part also. The small part at *E* is termed the hearth; the bottom is formed of a large fire-stone, supported by a mass of mason-work, having air-channels, as seen at *N*, while open arches or galleries, *P P P*,

are made below, one intersecting another at right angles, to keep the whole erection dry. D is the chimney surrounded by a gangway, with openings to admit the barrow, by which the furnaceman introduces the ore, flux, and fuel. C is the *throat* or *tunnel* hole of the furnace; A is called the cone or body; B the boshes; HH are arches leading through from one tuyere-hole to another, for convenience in attending upon the furnace. One of the stones composing the hearth, as shown at *r*, does not reach the base, but is supported by a strong bearer of iron built into the masonry, on which rests a block of sandstone called the *tymp*. Below, and a little in advance, is placed what is termed the damstone, *a*. The sides of the hearth are perforated a little above the level of the tymp with holes, *c c*, for the admission of the discharging orifices of the blowing apparatus, termed *tuyeres*; the arrangements of which will be shown in a future figure.

The preceding details will enable the reader to appreciate the points of resemblance and of difference in the following furnaces.

Fig. 281 represents a furnace which at one time was very common in Europe, and some specimens of which

Fig. 281

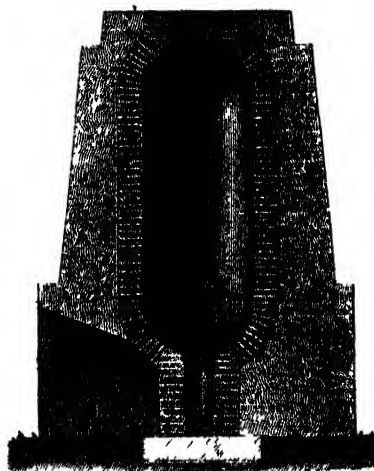


still exist in Spain and Hungary. It is exactly in the form of two crucibles, the one inverted over the other. This furnace measures from ten to sixteen feet in height, two feet wide at bottom and top, and five feet in the centre; two tuyeres are seen at *a a*, which admit the nozzles of two pair of bellows; in the front is an opening about two feet square, which, while in work, is built up with brick. After the furnace is heated sufficiently to permit the descent of the partially-fused metal, it is charged with the ore and charcoal fuel, and this is continued till, from the quantity of ore put in, the reduced metal would be up to near the tuyeres. The blast is then stopped, the front part, or breast wall, built up with brick, is removed, and the iron, which exists in a solid mass, is loosened and removed by grow-bars, and then carried to the forge hammers and wrought up into bar-iron. The front is again built up, and the smelting operations renewed. From the state in which

the iron is obtained, this furnace has been named the *salamander* furnace.

Fig. 282 represents what is termed the *blue oven*. This kind of furnace is in common use in Germany,

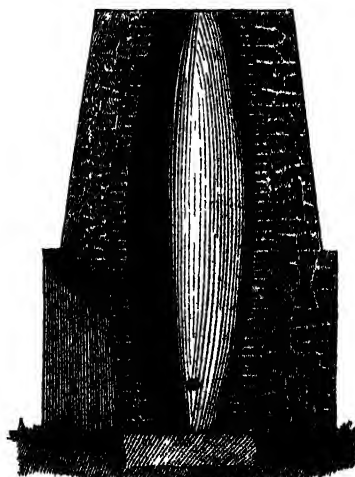
Fig. 282



and approaches near to our ordinary blast-furnace in the internal shape, its height is from twenty to twenty-five feet; *a* indicates the tuyere holes; it is also furnished with a breast, which can be removed; at the bottom, however, is a small hole, to let out the fluid metal, and a little above this, another to enable the scoria to be taken out. The bottom of the furnace is made to slope to the tap-hole. The fuel used is charcoal. This is considered an excellent furnace for spar iron ore, and yields a good steel-iron.

The form of furnace used in the Harz mountains is shown in Figs. 283 and 284. It is constructed of very

Fig. 283



heavy masonry. The crucible portion, *c*, is very high and narrow, while the boshes, *b*, are exceedingly flat, to allow of a very large body of coal and ore; the ores in that locality being very refractory, composed mostly of red

price. Only a few cargoes of this substance are annually obtainable. Its composition is subjoined:—

	Centesimally.
Moisture,.....	10.5
Organic matter and salts of ammonia,.....	62.5
Earthy phosphates,.....	17.0
Alkaline salts,.....	7.5
Sand, <i>et cetera</i> ,.....	5.2
	100.0
Ammonia per cent.,.....	21.1

ANALYSIS OF THE CHIEF PHOSPHATIC AND OTHER GUANOS—AVERAGE COMPOSITION FROM SEVERAL ANALYSES.

	Ichaboe; earlier importations.	Ichaboe; recent importations	Saldanha Bay	Patagonian.	Bolivian.	Chilian.	Kooria Moorla.
Moisture,.....	27.3	20.0	20.0	25.0	10.0	20.4	18.1
Organic matter and salts of ammonia,.....	34.3	24.4	14.9	18.3	21.7	18.6	12.4
Earthy phosphates,.....	30.3	20.4	56.4	44.0	51.5	31.0	42.7
Alkaline salts,.....	5.0	6.2	5.8	2.1	14.1	7.3	4.2
Carbonate of lime,.....	—	—	—	—	—	—	4.1
Sand, <i>et cetera</i> ,.....	3.1	29.0	2.9	10.6	2.7	22.7	18.5
	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ammonia per cent.,.....	7.3	6.0	1.47	2.5	4.5	5.47	2.05

The following is a simple method for analysing guano, which gives sufficiently accurate results for commercial and agricultural purposes. The sample of guano, which ought to be taken from different bags, is to be well mixed, and about two pounds of this taken for analysis. If there are lumps in the sample, these are to be finely pounded, and the whole repeatedly passed through a sieve so as to get a uniform mixture. To determine the moisture, about fifty grains are to be dried at 212° till they cease to lose weight.

For Ammonia.—If the sample is rich in ammonia, about twenty grains, and, if poor, about fifty grains are taken, a few drops of hydrochloric acid added to prevent the loss of this alkali, which takes place in some guanos on exsiccation, and then dried at 212°, and burnt with soda-lime, which must also be previously desiccated and cooled immediately before use. The mixture is introduced as rapidly as possible into the combustion tube. No appreciable loss of ammonia occurs if the substances are well dried before mixing. For ordinary purposes, sufficiently exact results are obtained by simply evaporating the chloride of ammonium on a water bath to dryness. One part of this salt represents 0.315 of ammonia.

Fifty grains of the sample are burned at not too high a temperature, till they cease to lose weight. The loss in weight represents the moisture, organic matter, and ammoniacal salts.

After being weighed, the ash is digested in warm water, filtered, and washed two or three times. The residue, dried and weighed, represents matters insoluble in water; the loss represents the soluble alkaline salts, which generally consist of chlorides and sulphates; and in the case of the better class of guanos, such as Peruvian, also of alkaline phosphates. The aqueous filtrate may be divided into two portions, in one of which the phosphoric acid is determined by the addition of sulphate of magnesia, ammonia, and chloride of barium. The hundred parts of the precipitate are dried, and weighed, and the weight of phosphoric acid. It is to be dried almost to dryness about 212°.

tion of the fluid, and to test for the presence of potassa, soda, sulphuric acid, and chlorine.

The ash left by the water is treated with dilute hydrochloric acid, filtered, and the residue washed and weighed. The undissolved portion is sand, clay, and, in recent or adulterated guanos, gypsum. By boiling the residue for half an hour in a concentrated solution of carbonate of soda, filtering, washing the residue, and then acting on it in the filter with dilute hydrochloric acid, and again washing, the gypsum will be tolerably well removed from the sand and clay. The difference in weight represents the sulphate of lime. If gypsum is present, the portion of this dissolved in the watery solution is apt to be reckoned as soluble alkaline salts: correction should be made for this.

The hydrochloric-acid solution is precipitated by ammonia, and the earthy phosphates filtered, dried, and weighed. The precipitate obtained by ammonia when added to the sand and gypsum, ought to be nearly the same as the weight of ash left by the water. When this is not the case it is due to impurities, such as carbonate of lime, and the loss of weight corresponds to the quantity of this substance present.

Adulterations of Guano.—From its high price there is no manure so subject to adulterations as guano. The substances generally made use of for this purpose are sand, marl, limestone, clay, powdered bricks or tiles, gypsum, chloride of sodium, *et cetera*. One or more of these substances mixed with the strong smelling guanos, such as the Ichaboe, and by the addition of a few feathers, form altogether so prime-looking an article, that even experienced buyers are deceived by it. Chemical analysis alone can reveal the deception.

Various simple experiments have been proposed to enable inexperienced unscientific persons to say whether a given sample of guano is or is not sophisticated. The conclusions are drawn from the specific gravity, the color of the ash, effervescence with an acid, *et cetera*. But such conclusions would only be correct for certain guanos, and not for all.

The following are the means by which adulterations of guano can be detected.

When burnt it leaves a perfectly white ash, when pure; but if adulterated with sand, marl, *et cetera*, the ash is more or less of a brown, or reddish-brown color. On the addition of strong acetic acid or hydrochloric acid to the ash, there is no effervescence if pure, but strong effervescence if adulterated with marl or chalk.

On the Mode of Estimating the Money Value of Guano.—If the money value of a manure is to be calculated, it is only necessary to ascertain the prices at which its valuable ingredients can be purchased in the market. Agricultural chemists have endeavored to fix the market value of the different constituents of manures, but their scales are not uniform. The following table gives the value per ton of the different constituents of manures, according to four different agricultural chemists:—

	Wey	Hodges.
Ammonia,	£56 0 0	£56 0 0
Insoluble phosphates, ..	7 0 0	7 0 0
Soluble phosphates, ..	32 13 0	25 0 0
Potassa,	30 16 0	20 0 0
Alkaline salts,	1 0 0	1 0 0
Organic matters,	1 0 0	0 10 0
Gypsum,	0 0 0	0 0 0

	Nesbit	Anderson.
Ammonia,	£60 0 0	£56 0 0
Insoluble phosphates, ..	8 0 0	7 0 0
Soluble phosphates, ..	24 0 0	28 0 0
Potassa,	0 0 0	20 0 0
Alkaline salts,	1 0 0	1 0 0
Organic matters,	1 0 0	0 0 0
Gypsum,	1 0 0	0 0 0

Discarding the decimals below 0.5, reckoning those above 0.5 as an additional unit, and leaving out of the calculation the value of the organic matter and potassa, the price of Peruvian guano would be the following, supposing the market value of its constituents to be as above stated according to WAY:—

	Value per ton	Total
Moisture,	13.67	—
Organic matter,	52.05	—
Earthy phosphates, ..	23.0	£7 0 0
Soluble phosphates, ..	7.0	32 13 0
Alkaline salts,	10.0	1 0 0
Potassa & kalies,	3.0	30 0 0
Ammonia,	16.50	56 0 0
		924

SPECIAL MANURES.—Bone Manure History.—Bone manure is said to have been long in use in hothouses in Germany, whence it was first introduced into England. ARTHUR YOUNG in his Northern Tour, 1770, mentions, that in the neighborhood of Sheffield bones were a very common manure for grass. About the same period, bones were used for turnips and arable crops in the limestone district of Yorkshire, and Lincolnshire. Like guano, it was at first received with distrust, and only after many years took its place in agriculture as one of the most valuable special manures known. In 1823, the declared value of bones imported into Great Britain was only fourteen thousand three hundred and ninety-five pounds sterling, and in 1837, it was two hundred and fifty-four thousand six hundred pounds sterling. In 1815, the quantity imported into Hull was about eight thousand tons, in 1833, it was seventeen thousand five hundred tons, and in 1835, was twenty-five thousand seven hundred tons. The chief supply comes from *France* and Russia,

and from the coasts of the Baltic. The earlier form of using this manure was as calcined bones, or when uncalcined, they were broken in pieces and distributed at the bottom of the manure heap, to undergo decomposition. In 1840, an increased impetus was given to the employment of bones, by the recommendation of LIEBIG to render it more readily soluble and available to plants by the action of sulphuric acid.

Theory of the Action of Bones.—Bones consist of two portions, organic and inorganic, in the proportion of about thirty-three of the former, to sixty-seven of the latter. The chief portion of the inorganic part, the phosphate of lime, called in agricultural language, bone earth, is supposed by BERZELIUS, to be a peculiar basic compound of eight equivalents of lime, united to three of phosphoric acid, and having the following per centage composition:—

	Centesimally.
Lime,	51.12
Phosphoric acid,	48.88
	100.00

MITSCHERLICH and others, however, regard it with more probability as a compound of three equivalents of lime and one of phosphoric acid, its composition being

	Centesimally.
Lime,	53.86
Phosphoric acid,	46.14
	100.00

The thirty-three per cent. of organic matter yield, by decay, about five and a half per cent. of ammonia. Hence fresh bones are valuable as a manure for the large quantity of earthy phosphates they contain, and the considerable amount of ammonia they are capable of yielding.

LIEBIG's axiom is, that no special manure can be of any use if the soil does not possess the other ingredients necessary to the crop. Bones are, therefore, only valuable when these conditions are fulfilled. Under such circumstances they have been proved to be the manure for turnips.

As bones furnish only two substances to crops, science as well as experience indicates that they are more likely to be useful when used as auxiliaries—for example, with farmyard manure, *et cetera*. At all events, that this is true, when bones are to be used for some years, may be deduced from the mineral theory. A striking instance of this fact occurred in Nottinghamshire. The soil was supposed to have become deficient in bone earth, and as the first applications produced very good results, it was supposed that by the constant repetition of a larger quantity increased fertility would follow. These hopes were disappointed, until it was shown by other experiments that other mineral constituents were necessary. By the addition of these, the accumulated stores of dormant bone earth immediately began to develop wonderful effects. This is but another instance of the truth of the mineral theory of LIEBIG.

The rapid fertilizing effects of bones depend on the state in which they are presented to the roots of plants. When buried in the entire state, they undergo decomposition very slowly. Hence it has been found neces-

sary to make them more rapidly available by grinding them, in which state they undergo fermentation readily, are reduced to powder, and thus made more soluble; or the ground bones, instead of being allowed to ferment, are first acted on by sulphuric acid, by which they are converted into a soluble form, known under the name of superphosphate.

Steamed Bones.—Mr. BLACKALL found, that bones submitted to high-pressure steam decomposed rapidly in the soil. This method was recommended by him as a good process for agricultural purposes. Others have found it necessary to crush the bones after steaming, to render them fit for application. In this method there is a loss of nitrogen in the gelatin dissolved out by the steam.

Fermented Bones.—Another mode for the decomposition of bones, so as to render them more readily available, is by fermentation. The process consists in mixing the bones with earth, ashes, farmyard manure into a compost, and leaving them to ferment. Certain substances, such as peat-ashes, have been supposed to cause this action more rapidly. Mr. PUSEY showed in 1847, that by mixing bones with an inert substance, such as sand, and watering the heap, and then closely covering up the whole with earth, putrefactive fermentation was generated.

The process would be still more effectual, and produce a better mixture, if instead of sand, wood or peat ashes were added to the ground bones, and urine employed to moisten the mass instead of water. As there might be a loss of ammonia by the heat generated, it would be advisable to spread a layer of sulphate of lime between the bones and the covering of clay; or to mix two or three hundredweight of gypsum with every ton of bones.

Dissolved Bones.—*Superphosphate of Lime.*—This term is bestowed on the commercial mixture of bones and sulphuric acid rendered dry by various absorbents. The mixture consists essentially of neutral phosphate of lime, which is scarcely soluble in water; biphosphate of lime, which is quite soluble; and sulphate of lime.

If the composition of the neutral phosphate of lime be taken according to BERZELIUS, as

Phosphoric acid,	48.5
Lime,	51.5
	100.0

and the biphosphate, as containing

Phosphoric acid,	71.5
Lime,	28.5
	100.0

Then one hundred parts of neutral phosphate can be converted into sixty-eight parts of biphosphate by the removal of thirty-two parts of lime by sulphuric acid. But as the materials from which superphosphate is manufactured, namely, bones, coprolites, *et cetera*, are not pure neutral phosphates of lime, a larger quantity of sulphuric acid is required. The average composition of raw bones may be taken as the following:—

Water, fat, and cartilage,	48
Phosphate of lime, with a little phosphate of magnesia,	46
Carbonate of lime,	4
Alkaline chlorides and sulphates,	2
	100

If the whole of this is to be converted into biphosphate, the following quantities of sulphuric acid, of specific gravity 1.70, would be required:—

	Pounds
To neutralize the carbonate,	4
To convert the whole phosphate into biphos- phate	25
Total,	29

Provided the bones are finely ground, and the acid and crushed bones well mixed, theory would indicate that, by employing sulphuric acid to the extent of one-third of the weight of the raw bones, the whole of the bones would be converted into biphosphate.

Superphosphate of Lime from Coprolites.—Coprolites have been extensively used as a substitute for bones in the manufacture of superphosphates, but they do not produce so good an article. They are very hard, and unless well ground, which is frequently not the case, they are not readily acted on by acid; moreover, a larger quantity of acid is also necessary, as they contain a larger proportion of carbonate of lime.

Practical Rules for the Manufacture of Superphosphate of Lime.—The essential condition in this manufacture is, to reduce the bones or coprolites to be acted upon to as fine a state as possible before applying the acid. The sulphuric acid, mixed with twice its bulk of water, or further diluted with due regard to the subsequent drying, is added by degrees to the crushed materials, which are kept constantly stirred so as to bring all parts into contact with the acid. The absorbents, which are either ashes, mould, bones, coprolites, or some such materials, are then to be added, till the mass is sufficiently dry. Where machinery cannot be had, the following modification of a plan proposed by Mr. PUSEY has been found useful, on a small scale, for the conversion of eighty bushels of bones. A circular wall, in height about two feet, is formed of ashes. The space inclosed is about ten feet. The crushed bones are passed through a fine quarter-inch sieve. The coarser particles are laid flat in the centre, and the finer are placed round the ring, close to the ashes. Water is then added to the bones so as thoroughly to saturate them, after which they are turned over frequently in the course of a few hours. If a sufficient quantity of water has been added to the bones, it is not necessary to dilute the acid any further. If one part, by measure, of acid is to be used with three parts of water, it is better to use one-half of this water to saturate the bones, and to dilute the acid with the other half of the water. After the bones have been turned the acid is added gradually, the bones being constantly turned and mixed with the spade. In six or eight hours after the addition of the acid, the fine bone-dust, forming the second circle, is thoroughly mixed with the bulk. Next day the ashes forming the outer wall are thrown over the heap, which is then left undisturbed for a week. The heap is then opened out and thoroughly mixed with the ashes, and finally passed through a sieve. If not sufficiently dry for this last operation, a further quantity of ashes may be added to it.

Composition of Superphosphate of Lime.—It is extremely difficult to give the average composition of superphosphate of lime, which might serve as a standard

agriculturists to call in the aid of science. The few years in which science and practice have been united have already effected the solution of many contradictory and crude opinions, based on blind empiricism, by showing wherein really consisted the value of manures, and the proper mode of treating them, so as to obtain their maximum fertilizing effects, and by directing attention, on well-grounded principles, to many hitherto-neglected sources of manures. The old struggle still continues between blind practice and the new views. The energy of the numerous scientific men who now devote their talents to agricultural chemistry leads, however, to the hope that, in a few years more, the laws which govern the proper tillage of the ground will be more thoroughly investigated and understood; agriculture will then take its stand as a more exact science than at present, and the cultivation of crops can then be entered upon as an art with as much certainty as any other manufacture.

ARTIFICIAL MANURES.—Twenty-five years ago, when the manufacture of spa and mineral waters began, they met with violent opposition from the members of the faculty, as being deprived of all the good qualities of the natural ones—as wanting, in a certain *conditio, sine qua non*—in a *spiritus rector*, or vital power, which alone gave them any medicinal qualities. Those times have passed now; chemistry has demonstrated to a certainty what the constituents of those various waters are, and under what forms and compounds they are united in them. It has succeeded in combining them exactly in the same proportions, and in rendering them not only equal to the natural ones, but *even more effective*. Physicians now connect certain effects on the human body with certain elements in the waters, and are enabled, by the light of science, to add more of this element, or more of that; nay, to apply, instead of the waters themselves, the one active element alone, as is, for instance, the case with iodine in indurations and struma. It is well known that at this moment there are extensive manufactories of mineral waters in England, at Berlin, at Dresden, at Vienna, *et cetera*. The mineral waters which are manufactured by the Messrs. ELLIS at Ruthin, in North Wales, and by a few other firms, are in every respect equal, if not superior, to the natural ones. Now, the Editor believes that the same principle may be applied, partially at least, to the use of manufactured manures; and, in fact, this is proved by the success that has attended the application of several. To dwell at large upon all the artificial manures that are now manufactured in hundreds and thousands of tons annually, would occupy more space than is at the Editor's command; he will, therefore, only append the analyses of those which have come under his immediate notice, and which have been eagerly sought after by the agriculturist. The recipes may be improved, no doubt, still the manufacturers of artificial manures may profit by studying the various per centages of the different constituents in each. Three of the best have been selected out of numerous samples that have been analysed by the Editor. No. 1 is a manure manufactured by Messrs. KNIGHT and Company, Widnes, near Warrington, an inspection of whose works will prove

interesting to the agriculturist. No. 2 is made by the British Patent Manure Company in Manchester; and No. 3 is produced at the Runcorn Bone Works. Most satisfactory results have been obtained wherever the composts have had a fair trial:—

	1.	2.	3.
Water,	24.00	12.07	20.00
Sulphate of ammonia,	10.84	15.97	14.85
Phosphate of lime and magnesia,	35.50	16.84	24.07
Biphosphate of lime,		10.11	6.81
Sulphate of lime,	9.16	5.40	7.20
Sulphate of magnesia,	—	6.72	—
Alkaline chlorides,	1.08	4.12	.54
Silicate of potassa,	—	5.47	—
Nitrogenous organic matter	1.40	13.29	20.31
Insoluble matter, <i>et cetera</i> ,	18.02	10.01	6.22
	100.00	100.00	100.00

In concluding this article, the Editor feels great pleasure in expressing his thanks to his talented friend, Dr. BLYTH of the Queen's College, Cork, for much valuable matter that he has supplied during its compilation. The Editor could not have had a more competent contributor, for Professor BLYTH was for many years the agricultural chemist at the college of Ciren-cêster, where daily, under his inspection, were carried out experimental researches on the different kinds of manures.

MERCURY.—*Mercure*, French; *Quecksilber*, German; *Hydrargyrum*, Latin.—Mercury is a substance which has only of late been raised to the dignity of a metal, notwithstanding its being known long before the Christian era, and extensively experimented upon, more especially whilst the powerful idea of transmutation, and of the *elixir vita*, possessed the minds of the first chemical students—the alchemists. Its characteristics are very marked, and in one respect different from any other known metal, namely, its fluidity at all ordinary temperatures. It was this property, coupled with its silvery whiteness and metallic lustre, which determined its other popular name, quicksilver. Though it is not spoken of in the ancient scriptural writings, still THOMSON in his *History of Chemistry*, states, that its discovery must have preceded the earliest historical records. It was common in the time of MOSES; for, according to Dr. HERBERT, the Egyptian magi employed it in their so called *enchantments*, when every man cast down his rod and it became a serpent. ARISTOTLE relates, that DÆDALUS gave motion to a wooden Venus, by means of a current of mercury. DIOSCORIDES describes a method for its reduction from cinnabar, or *minium*, as it was then designated, and which is remarkable as being the first record of a process that led to distillation. The metal in those times was employed in gilding, much in the same way as at present, and the minium or cinnabar had its application in painting and decoration. PLINY mentions that CALLIAS, an Athenian, was acquainted with the preparation of the mercuric sulphide. The Greeks converted considerable quantities of the latter compound to this use, and were in the habit of drawing their supply from Spain, the mines of which were known and worked seven hundred years before the Christian era. In latter times the virtues of the sulphide as a medicine was established, and this, as well as the metal, was extensively administered by the professors of the healing art.

DIOSCORIDES, who cites some of the properties of the metal, had, it is evident, but an imperfect knowledge of it; for he states, that it could be retained in vessels of glass, tin, lead, or silver—an assertion which is now well known to be untrue, especially with regard to the metals that he named. PLINY also seems undecided as to its true nature, since evidently he thought that there was some radical difference between the mercury which was found in the virgin state and that obtained by the manufacture of the time. The former was known as quicksilver—*argentum-vivum*—and the latter as mercury—*hydrargyrum*. This doubt lurked in the minds of even the learned alchemists and philosophers till towards the close of the seventeenth century, when both kinds were submitted to numerous distillations—as in the case of BOERHAAVE, who distilled the same portion of mercury successively five hundred times, and the products were found to coincide in weight and all the then known properties. Still, at this period, owing to its fluidity especially, it was regarded as an imperfect or semi-metal, containing a principle regarded as pure vitrifiable earth—the silica of modern time. The fact of this terrestrial principle conferring solidity upon such bodies as contain it in abundance, being directly opposed to the fluid condition of mercury, induced BECCHER, an investigator of the first half of the seventeenth century, to admit the existence of another principle, a *mercurial earth*, which was supposed to possess weight and volatility to a very great degree. This chemist regarded quicksilver as a compound of three substances—namely, the vitrifiable, the inflammable or phlogistic, and the mercurial. He was supported in his views by STAHL and other learned semi-alchemists, till by the introduction of a course of experimental research and deductions, the nature of bodies came to be regarded in a simpler but truer light, which overthrew the hypothetical obscurity that pervaded all chemistry up till that time.

The knowledge that it could be solidified, acquired by the academicians of Petersburg in 1759, was the first means to remove the notion of its semi-metallic nature, and inquiries to which the announcement of the fact gave rise in the hands of PALLAS, HUTCHINS, BIEKER, BLAGDEN, and several others, led the way to its recognition as a true metal, and elementary body.

PREPARATION.—Several methods are known for the production of mercury from its saline combinations, many of which are practised on the large scale, and will consequently be described when treating of its smelting, but as these do not yield a pure metal, reference will be here made only to the methods that are calculated to afford such a product.

The mercury of commerce, which usually is contaminated with variable portions of lead, tin, and bismuth, may be distilled with one-tenth of its weight of cinnabar; and provided the distillation be carefully effected, the foreign impurities will be found in the retort, in the form of sulphides, after the pure mercury has passed over into the receiver. A purer product is, however, obtained when carefully prepared cinnabar or corrosive sublimate—chloride of mercury—that has been continuously sublimed, is distilled with one part of quicklime or iron filings. The principal part of the impu-

rities is removed in the formation and sublimation of the sulphide or chloride taken, and the last traces are retained, with the sulphide of calcium, or iron, generated in the second part of the process. Sometimes agitation with concentrated nitric or sulphuric acids has the effect of rendering mercury much purer, but, in any case, can the product obtained by the process described be excelled. To ascertain its purity, it is only necessary to dissolve a portion in an excess of nitric acid, evaporate the solution, and heat the dry salt to redness; or fuse the metal with pure sulphur, and sublime the product in a glass matrass; in either case nothing should remain if the metal be pure, but if a residue appear, the impurities are proportionate to its weight. Observation has led to the adoption of a simpler, but less reliable test than the above; it is this, that pure mercury when dropped upon a smooth, but slightly-inclined surface, breaks up into drops which retain the spherical form, but if contaminated with tin, lead, or such adulterants or impurities, the form of the globules will appear elongated, so as to present or leave a tail.

PROPERTIES.—Mercury is a metal that possesses the metallic lustre in a high degree, and exhibits a silvery whiteness. It is fluid at all temperatures between 39.5° Fahr., and its boiling point, which is variously estimated by different experimenters, as ranging between 654.8° CHEMISTON; and 680° DULONG and PETIT—DALTON estimating it at 660.2°; and HEINRICH at 672.8°. At minus 40° it solidifies, and while in this state permits of being beaten out under the hammer, welded, *et cetera*, like other metals. When the refrigeration is effected by means of solid carbonic acid and ether in a dish, and if the yet unsolidified portion be poured off, the metal adhering to the walls of the vessel will present well defined octahedral crystals. Its density varies with the degree of temperature more than any other metal, owing to the freedom with which it expands. SCHULZE found it in the solid state to be 14.391. REGNAULT estimates the gravity at — 40° to be 14.4, but if it could be compressed by hammering, the number would doubtless be higher. At 39.2° KOPP estimated its gravity at 13.594; KUPFFER at 13.588, and 13.535 at 78.8°; at the latter degree the number arrived at by CAVENDISH and BRISSON was 13.568; by FAHRENHEIT 13.757. KARSTEN determined its density at the ordinary temperature to be 13.559. Various researches show that this metal evaporates at common temperatures, as well in contact with air as *in vacuo*. This may be proved by suspending gold leaf in a flask containing some of the metal, when, after a few weeks, the lower portion of the leaf will appear amalgamated. KARSTEN asserts that at 32° mercury gives off as much vapor as to develop the image on a daguerreotype plate held over it at a convenient distance. BRAME affirms that sulphur in a finely-divided condition, as when precipitated from a state of vapor, is much more delicate than gold leaf. By its aid he found that at 53.6°, the tension of the vapor rises to the height of three feet, and even higher than this; but, in the latter case, the delicacy of the known tests is inadequate for its detection. This investigator is also of opinion that in air and vapor of sulphur, the vapor of mercury diffuses itself according to the law which governs other gases.

The specific gravity of the vapor of mercury was found by DUMAS to be 6.976, and by MITSCHERLICH 7.03—the latter number being that arrived at by theory. The property of expansion which mercury possesses, and the long range of temperature through which it exhibits this property, with remarkable regularity, render it peculiarly adapted to the wants of the philosopher for determining the sensible heat of bodies. Repeated experiments have shown, that between 32° and 212°, the increase of bulk which it acquires, by the acquisition of equal increments of heat, is extremely regular, and corresponds to 0.00011 of its bulk at 32°, according to the experiments of DALTON. Between 38° below zero—the lowest degree of temperature that can be safely estimated by the mercurial thermometer—and + 32°, the freezing point of water, the gradation is not so regular, although the difference is so trifling as to be disregarded in most applications; but between 212° and 662°, it has been found to pass from the regular expansion observed between the limits of the freezing and boiling points of water, and to increase in this respect as the heat becomes more elevated. The annexed table exhibits the ratio of expansion of mercury between 32° and 212°, as determined by the investigators mentioned:—

•0200	.....	Dalton.
•01887	.....	Cavendish.
•01848	.....	Lavoisier and Laplace.
•01818	.....	Hallstrom.
•01801	.....	Shuchburgh.
•01800	.....	Dulong and Petit.
•01781	.....	Deluc.
•01695	.....	Roy.
•018153	.....	Milner and Regnault.

The following numbers, arrived at by DULONG and PETIT, show the variable and increased expansion of mercury above air by equal increments of heat:—

COMPARATIVE EXPANSION OF AIR AND MERCURY BY THE SAME INCREMENTS OF HEAT.

Dulong and Petit.		Rudberg.	
Air	Mercury	Air	Mercury
0°	0°	35.96	36°
100°	100.0	0°	0°
150°	151.3	+ 50.04	+ 50°
200°	204.6	100°	100°
250°	255.1	198.81	200°
300°	314.15	294.73	300°
350°	360.00	—	—

Mercury is not acted upon when exposed to air, oxygen, nitrogen, nitrous or nitric oxide, or carbonic acid gases. On the contrary, if shaken with water, ether, oil of turpentine, or fatty unctuous matters, it loses its metallic appearance, and is converted into a grey *athlops per se*, in which the metal is not altered but *deadened*—that is, reduced to minute and isolated globules by the interposed stratum of the compounded matter. Ordinary mercurial ointments retain the metal in this state, but so finely divided as to render its detection by the unaided sight impossible. When pure it is tasteless and inodorous, although a peculiar odor has been observed when it is rubbed between the fingers. ~~Scoured upon dry bodies~~, it does not wet them like other liquids, but flows off in drops, except in the case of the metals with which it forms amalgams. On this account it is designated, sometimes, in old writings, *aqua non*

ma deficiens manus—water that does not wet the hands. Kept at a temperature approaching ebullition in contact with air, it suffers oxidation slowly. Water is not decomposed by it. The nitrous, nitric, iodic, chloric acids, *et cetera*, easily oxidise it without the aid of heat; sulphuric acid, when diluted, has no action upon the metal, even when aided by heat, but concentrated acid, at a high temperature, readily converts it into a proto-sulphate, sulphurous acid being eliminated. With selenium, sulphur, phosphorus, chlorine, bromine, and iodine, it unites with facility, giving rise to the haloid mercurial compounds of those radicals. It quickly combines with the noble metals—also with tin, lead, bismuth, zinc, and most of the soft metals, giving rise to amalgams which often possess particular interest. This is the case, more especially in a manufacturing sense, with the amalgams it constitutes with gold, silver, platinum, as they are available in the smelting or abstraction of these metals from the gangue in which they may be distributed. Indeed, a chief portion of the mercury annually extracted is devoted to this special application, so that a distinct relation between the yearly production of gold and mercury may be traced. Besides this application it has many others, such as gilding, plating, and the like. Many of its compounds are valuable in other branches of art, such as medicine, painting, *et cetera*, but more particularly in the former, where its administration is very varied and frequent. The metal is likewise very advantageous to the anatomist, who employs it as an injection, either alone or in the form of vermilion suspended in size. There are many other instances of its application, but not being very general, they will not be further dwelt upon.

Atomic Weight.—Before proceeding to notice the ores of mercury and the processes by which the metal is obtained from them, it may be mentioned that much difference of opinion has existed respecting the atomic weight of this element. The mercurial oxides are two in number—the *grey* and the *red*; and it is from the different views chemists have taken of the constitution of these bodies that 100 and 200, or a near approximation, have been respectively proposed as the equivalent of mercury. The composition of these bodies, denominated mercurous and mercuric oxides, is thus centesimally expressed:—

	Grey Oxide,	Red Oxide,
Mercury,	96.15	92.59
Oxygen,	3.85	7.41
	100.00	100.00

Now, if the *grey* be assumed to be the *protoxide*, then the value of an equivalent of mercury capable of saturating a full equivalent of oxygen, which is represented by 8, will be 199.8, or nearly 200; whilst, on the other hand, assuming this oxide to be the suboxide, and, halving that number, it will be represented by two equivalents of metal, and one of oxygen. Taking the equivalent of the metal, then, at 100, the atomic constitution of these oxides is thus represented:—

	Grey oxide.	Red oxide.
1 Eq. Mercury,	200	100
1 Eq. Oxygen,	8	8
1 Eq. Grey Suboxide, 208		1 Eq. Red Protoxide, 108

The chemical symbol of the metal is taken from its Latin name, and is written Hg.

BERZELIUS, ERDMANN, MARCHAND, GMELIN, REGNAULT, THOMSON, GRAHAM, and many other chemists, have adopted 100 or something near it as the true atomic weight, and the preference is further justified by the fact, that though both oxides are salifiable, yet the grey is very unstable, and unlike a true protoxide in its characters, whilst the red is eminently persistent and basic; indeed, according to BRANDE, it almost approaches to alkalinity. Besides, the evidence adduced from the connection of the atomic heat of the metal with its atomic weight is decidedly favorable to that number which expresses the grey as a *sub*, and the red as a *protoxide*. The experiments of STRANBERG, published in the Memoirs of the Academy of Stockholm for 1845, go to prove that the atomic weight of mercury cannot be less than 99.90.

ORES OF MERCURY.—The minerals into the composition of which mercury enters, are by no means numerous, and few of them are important. The metal itself occurs native in the form of fluid globules scattered through its gangue. The quicksilver mines of Almaden in Spain, of Idria in Carniola, of Wulfstein and Morsfeld in the Palatinate of Rosena in Hungary, and Sala in Sweden, supply specimens of the virgin metal, which was said at one time to fetch a higher price than that obtained by reduction. In some places native mercury is so plentifully dispersed through its ores, that when an opening is made it escapes, and trickling out, collects in considerable quantities at the bottoms of the levels.

A native amalgam of silver, amorphous and crystallised, is also met with. Not unfrequently this mineral occurs in the form of flattened plates. A specimen, said to be from Peru, the specific gravity of which Dr. DALZELL determined, did not exceed 13.995, but usually it is 14.119. From the average of the analyses of three specimens examined some years ago by the same chemist, along with the analysis of other specimens by KLAPROTH and CORDIER, it consists centesimally of—

	Dalzell.	Klaproth.	Cordier.
Mercury.....	58.1	64.	72.5
Silver.....	43.9	36.	27.5
	100.0	100.	100.0

That the composition of this mineral should vary considerably does not seem surprising, since it has been proved that mercury evaporates from mercurial ointment and amalgams. *Argyritis*, an argenteous amalgam of great value, is found in considerable quantity in the province of Copquimbo in Chili. It contains 13.5 parts of mercury, and as much as 86.5 per cent. of silver. Indeed, this is one of the chief ores of silver in the rich mines of Arguiros. An amalgam of gold, analysed by SCHNEIDER, and which occurred along with platinum ore from Columbia, contained mercury 57.40, gold 38.39, and silver 5.0. Native amalgams of lead, containing selenium, have been analysed by ROSÉ.

Horn quicksilver—subchloride of mercury, or native calomel—is found associated with the other ores of quicksilver at Idria, at Denx-Ponts, in Spain, and elsewhere. It is a yellowish or ash-grey mineral, sectile, and subtranslucent. Sometimes it occurs as a crust, or forms granular concretions. At other times it crystallizes in four-sided prisms. Its specific gravity is 6.482, whilst that of the powdered calomel of the shops is 7.14, and that of the crystallized factitious subchloride is 7.2.

Iodides, bromides, and selenides of mercury also occur, but rarely. The iodide has been met with in Mexico, associated with the selenide. A specimen of the bromide Dr. DALZELL found to contain, besides bromine, traces of iodine, selenium, and sulphur. ROSÉ has described the selenide as composed of selenium 6.49, sulphur 10.30, and mercury 81.33.

The principal ore of mercury is the sulphide—the *zinnobar* of the Germans and *minium* of PLINY. The color of native cinnabar varies from cochineal red to brownish-red and leaden grey. The streak is scarlet, and the lustre usually adamantine. The density of this mineral is 8.098, and when pure it contains 86.29 parts of mercury with 13.71 of sulphur. Specimens of the purest ore have, occasionally, all the richness of hue which the best vermilion presents.

The following table shows the composition of cinnabar from various quarters of the world, the amount of the constituents being centesimally expressed:—

	Mercury	Sulphur	Bituminous matters	Gangue	Water	Carbon.	Silica	Alumina.	Iron	Copper	Lime	Magnesia	Total.	
Japan,	84.50	14.75	—	—	—	—	—	—	—	—	—	—	90.25	Klaproth.
"	79.30	14.50	—	—	—	—	—	5.67	—	—	0.63	—	100.10	Dalzell.
Idria,	51.80	8.20	6.80	32.0	3.20	—	—	—	—	—	—	—	102.00	Lebererz.
Idrian } ..	81.80	13.75	—	—	0.73	2.30	0.65	0.55	0.20	—	—	—	99.00	Klaproth.
Swaore, } ..	85.00	14.25	—	—	—	—	—	—	—	—	—	—	99.25	"
Neumarktel, } ..	18.00	—	—	—	—	—	—	—	73.31	—	—	—	91.31	Bealey.
Wulfstein, } ..	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Almaden,	37.84	16.22	—	—	—	—	85.12	—	—	—	—	—	89.18	"
"	37.75	16.22	—	—	—	—	35.12	—	—	—	—	—	—	"
"	86.94	15.97	—	—	2.58	—	42.79	—	traces.	—	—	—	98.28	Dalzell.
"	41.79	16.72	—	—	—	—	41.49	—	—	—	—	—	100.00	"
California, ...	69.36	11.38	—	—	—	—	14.30	0.61	1.23	—	1.40	0.49	98.77	Bealey.
"	70.13	11.21	—	—	—	—	14.52	0.61	1.23	—	1.40	0.49	99.59	"
"	70.23	11.21	—	—	—	—	14.52	0.61	1.23	—	1.40	0.49	99.59	"
"	72.00	12.80	—	—	—	—	—	—	14.0	—	—	—	100.00	Dalzell.

Geologically, the ores of mercury occur amongst stratified deposits. The volatility of the metal may account for its not being met with in any large quantity in

crystalline or igneous rocks. Thus, it is found most abundantly in the independent coal formation, and in beds lying between primitive argillaceous schistus and

Wedge and Jasper-ware.—Amongst this celebrated description of fine stoneware, the manufacture of Mr. Wedgwood may be enumerated those known as *onyx*, *basalt*, *granite*, and *porphyry*; and from the particular composition of their bodies are capable of receiving the most exquisite degree of finish and delicacy in their manipulation, rivalling in beauty of form and chasteness of outline the art productions of the ancients.

One of the most remarkable of these bodies is the *jasper* or *onyx*, which presents to the eye a white biscuit of a porcellaneous nature, and which has the property of receiving, through its entire mass, by the admixture of metallic oxides, the same colors that those oxides would impart to glass or enamel in a state of fusion. This property, peculiar to itself, renders it applicable in a manner no less pleasing than extraordinary to the production of *cameos*, *portraits*, *vases*, and all subjects which require to be shown in relief, the ground being made of one color, while the raised figures are of the purest, most delicate white.

The composition of this jasper or onyx body may be given as follows, the blue color being imparted by the admixture of oxide of cobalt, in proportions varying from one-third of a part to one part per cent., or more, according to the depth of tint required:—

White Jasper bodies.	II.	III.	IV.	V.	VI.	
Sulphate of barytes, ...	150	40	30	50	32	160
China clay,	35	—	—	15	10	60
Blue clay,	45	20	12	35	25	90
Flint,	35	—	3	10	8	40
Gypsum, ...	6	—	—	—	1	8
Cornish stone,	50	20	20	—	7	—
Bone,	—	—	—	25	—	—

The proportion of *stain* being one part of cobalt to from fifty to seventy-five parts of the body, according to the depth of color required. The various other colored jaspers are obtained by the addition of other oxides to the several white bodies.

The *green* jasper is obtained by the admixture of the oxide of chromium.

This jasper body resembles so nearly in appearance the glassy vitreous substance of the ancient gems, that it has become celebrated throughout the world for the beautiful imitations of medallions, cameos, and vases it is capable of producing. It constitutes also the dark-blue ground, with its gem-like surface, of WEDGWOOD'S copy of the Portland vase, a sepulchral urn of great antiquity, discovered in the neighborhood of Rome between the years 1623 and 1644. The careful investigation of this gem of art has pronounced the body of the vase to be formed of a transparent glassy structure of a deep amethystine hue, but which, when viewed by reflection, appears black and opaque, while the raised figures on its surface are white glass, of a sufficiently transparent nature to admit of the blue color of the ground tinting their form through the thinner parts, while the thick possess sufficient opacity to appear of a pure white. The examination both of the ground and bas-reliefs lead to the belief that the blue body of the vase when formed, and still red-hot, was coated all over as far as the bas-reliefs were intended to reach with the white glass, and the handles applied afterwards while in the same red-hot condition—a fact demonstrated by

the intervention of a layer of this white enamel between the body of the vase and the lower extremity of the handles, the upper portions being in direct contact with the vase itself. The figures seem to have been produced by a subsequent cutting away of this white coating down to the blue ground, after the manner of real cameos.

The extent to which the manufacture of imitative ancient gems was carried in the Wedgwood jasper body was enormous, and is again considerably upon the increase at the present time; the original purity and other pristine qualities being revived at Etruria, the seat of the manufacture, by the energies of Mr. GEDFREY WEDGWOOD, the eldest son of the present FRANCIS WEDGWOOD, the descendant of the great JOSIAH WEDGWOOD. This, from the re-discovery, as it were, of the first jasper body, together with the possession of all the original models and moulds designed by FLAXMAN and others, renders it more than probable that the ware will again attain the high standing of former years, and that the mantle of the great WEDGWOOD will once more descend amongst his own people.

Manufacture.—In wares of this description the mass is frequently white, and only covered on the surface with a thin colored coating of the same body, the shrinking properties of the mass not being essentially affected by the addition of small quantities of the metallic oxides. The mass, after formation upon the throwing wheel in the usual manner, receives when sufficiently hardened the proper outline upon the lathe; and if a vase or other similar shape, such rims or fillets are turned as are intended to appear white upon the dark ground in the after manipulations. The piece is then taken into the dipping-room, where it is immersed in a tub containing the colored slip of a consistency approaching thick cream, and receives a thin even film over its whole surface. It is then allowed to harden until it is sufficiently firm to admit of being placed a second time upon the lathe, when a burnisher is run over it to give uniformity and smoothness to the surface; the blue dip, at the same time, being turned off, and exposing those portions intended to appear white, such as mouldings, lines, *et cetera*, produceable on the lathe.

The piece is then taken to the *decorator*, who affixes the various ornamentations intended to complete the design. Taking the vase in one hand, he with a small hair pencil moistens with water that portion of the surface intended to receive the pattern, which is affixed in its proper position by a very gentle pressure of the finger and the aid of a damp sponge; each separate ornament being added in this manner, until the whole decoration is complete. The piece is then sent into the oven to be fired in the usual way.

The ornaments in relief are obtained, like an impression from a seal, by pressure in a mould made of baked clay or plaster of Paris. The moulder sits at a bench with a number of these small moulds before him, a lump of the plastic material forming the body of the ware being placed at his side, and from which, by means of a small spatula, he separates pieces of the clay, and rapidly fills or presses them into three or four of the moulds. This done, he takes the one first

in order, and with the smooth flat end of his tool burnishes over the surface of the mould, removing the surplus clay, and causing the sharp-cutting edge of the die to give a clean sharp outline to the impressed clay, which, yielding slightly to the rubbing process by suction, leaves the mould, and is turned out on a slab for use by the decorator, who has to exercise considerable care and dexterity in preserving the sharp outline of the relief in its application to the ware. In the original WEDGWOOD fabrications, so much of the beauty of the piece depending upon this particular, the outlines were sharpened and restored by modellers before the ware was sent into the oven, producing such exquisite embellishments that now, sixty-five years after his death, connoisseurs are eager to purchase them at three times their original price. Those decorations, such as flowers, *et cetera*, which are not capable of receiving their form by pressure in the mould, are modelled by hand separately, and united afterwards piece by piece together. The other bodies of WEDGWOOD, which in composition resemble agate, jasper, porphyry, and other variegated stones of a vitrescent or crystalline fracture, are used largely in the formation of ornamental wares. These bodies are composed of various colored clays, placed in layers to represent when pressed together the several stones they are intended to imitate, care being taken that they shall not so amalgamate as to destroy the beauty of the imitation.

The *Basalt* or black Egyptian biscuit, so called from its resembling basalt in appearance and color, forms the mass from which the most esteemed forms of ancient Egyptian art are modelled, and which is enriched with bassi-relievi both in red and white; many articles

of domestic requirements, such as tea-pots, milk-jugs, ink-stands, *et cetera*, are moulded in the same style from this mass. In composition it may be given as follows:—

Basalt or Black Egyptian bodies.	I.	II.	III.	IV.	V.	VI.
Blue clay,.....	200	330	200	—	100	—
Red clay,.....	—	—	300	500	—	500
Ochre calcined,.....	200	300	100	75	100	—
Iron scales—protoxide of iron,.....	—	80	—	—	85	—
Manganese,.....	60	80	100	75	40	100

Red body—terra-cotta ware.

Red marl very carefully sifted,.....	10 parts.
Common marl,.....	2 parts.

with the addition of ten per cent. of Cornish clay, if a light color is required.

The revival of painting upon vases and other similar articles in the manner of the ancient Etruscans, without the glossy appearance of ordinary painting upon porcelain or earthenware—an art lost since the time of PLINY—is due to Mr. WEDGWOOD, who, after careful examination of original Etruscan vases, finding it impossible to imitate the colors by *enamels*, devised other substances, termed *encaustic* colors, producing an entirely different effect, and without any of the glossy lustre of the enamels in the firing. This discovery at once enabled successful imitations of the ancient vases to be made in all their variations of light and shade, and of equal durability with the enamels, without the defect of a varnished or glassy surface. Encaustic colors are applied with great ease and certainty, changing but little in the firing, and have no tendency to run or spread on the design. The composition for certain colors may be given as follows:—

ENCAUSTIC COLORS.

White.	Black.	Green.	Blue.
Blue clay,..... 20	Egyptian black,.... 12	White slip,..... 12	White slip,..... 25
China clay,..... 10	White slip,..... 2	Blue slip,..... 1	Blue cobalt,..... 1½
Flint,..... 10	Blue slip,..... 3	Nickel,..... 1	
Cornish stone,.... 5			

These clays, finely ground and brought to the consistency of thick slip, are painted upon the wares while in their moist state, and before firing in the biscuit oven.

It is impossible to conclude this notice of the jasper wares of JOSIAH WEDGWOOD, without quoting some remarks upon the manufacture of pottery which conclude his catalogue—dated and published in 1777—remarks peculiarly applicable to the manufactures and productions of the present day. He says:—

A competition for cheapness, and not for excellence of workmanship, is the most frequent and certain cause of the rapid decay and entire destruction of arts and manufactures.

The desire of selling much in a little time, without respect to the ~~taste~~ or quality of the goods, leads manufacturers and merchants to ruin the reputation of the articles which they make and deal in; and whilst those who buy for the sake of a fallacious saving, prefer mediocrity to excellence, it will be impossible for them either to improve or keep up the quality of their works.

All works of art must bear a price in proportion to the skill, the taste, the time, the expense, and the risk attending the invention and execution of them. Those

pieces that, for these reasons, bear the highest price, and which those who are not accustomed to consider the real difficulty and expense of making fine things, are apt to call dear, are, when justly estimated, the cheapest articles that can be purchased, and such are generally attended with much less profit to the artist than those that everybody calls cheap.

Beautiful forms and compositions are not to be made by chance, and they never were made, nor can be made in any kind, at a small expense.—*Wedgwood*.

Fine stoneware in general is never glazed, though at times a glaze is produced spontaneously with the firing by a process called *smearing*, the inner surface of the seggars being coated with a glaze composed of—

DRY SMEARS OR GLAZE FOR FINE WHITE STONEWARE.

No. 1.

Lead,.....	0
Stone,.....	3
Salt,.....	3

No. 2.

Flint,.....	10
Bone,.....	5
Nitre,.....	3
Salt,.....	5

No. 3.	
Lead,.....	4
Stone,.....	1
Salt,.....	2
Flint,.....	1

No. 4.	
Glaze,.....	4
Salt,.....	1
Potassa,.....	$\frac{1}{2}$

No. 5.	
Calcined bones,.....	3
Common salt,.....	1

No. 6.	
Bones,.....	5
Salt,.....	3

No. 7.	
Flint,.....	10
Bones,.....	5
Salt,.....	5
Nitre,.....	3

WASH SMEARS.

No. 8.	
Lime at twenty-four ounces,.....	3 quarts.
Slip at twenty-four ounces,.....	2 quarts.
Salt,.....	2 pounds.
Nitre,.....	1 pound.

The ingredients dissolved in hot water, and the seggars washed inside with the mixture.

This in part becoming volatilized during the firing, a portion of the alkali and oxide of lead is absorbed by the surface of the ware, forming a thin layer of glaze, both the surfaces containing silica appropriating a fair proportion of the vitrifiable bases. Sometimes a glaze containing a large quantity of lead or borax, is applied by the process described under *Porcelain* to either both or only one surface of the ware. When pigments are mixed with the glaze, colors—as is the case with yellow—are communicated to the ware which could not otherwise be produced. The firing of this kind of ware takes place in seggars, in furnaces of similar

description as those described under *Earthenware*, and often at the same time as wares of that description, being placed in those portions of the kiln where the temperature is highest.

Varnished and Larva Ware.—Other kinds of wares manufactured in Germany at Pirna and Saargemündt, and recently brought into extensive circulation for ornamental purposes, may be classed under fine stonewares, and possess a mass exhibiting a striking resemblance to porphyry or jasper, and capable of receiving the most delicate and refined forms in manipulation. The ware manufactured by UTZSCHNEIDER at Saargemündt exhibits several peculiarities—the contraction in the firing amounting to twenty per cent., while the mass is composed of three local varieties of clay, partly ferruginous, and quartz. The body, which is not glazed, but ground after firing with emery and polished with tripoly, requires the same precautions in the manufacture as that described under *Fine Stoneware*. The ware manufactured at Pirna on the Elbe has likewise a colored body, the chrome green and black masses being without glaze and dull; while the ochre-yellow mass of other varieties is often concealed by a coating of very brilliant varnish color, very different to potters' pigments, from its soft nature, fatty lustre, and easy destructibility in the fire, being, in fact, an oil paint. This varnish is laid on very smoothly and with great care, to preserve the outlines of the ornaments in relief, and afterwards when dry covered with a thin coating of copal varnish. It is secure from injury by hot water, but neither withstands abrasion by the knife, or use over the fire. Fine stoneware, as a general rule, does not stand well against heat or sudden changes of temperature.

The relative values of plastic clay for the manufacture of *fine* and *common* stoneware, with and without glaze may be here given—

STONEWARE GLAZED.

Place.	Silica.	Alumina.	Oxide of Iron.	Lime.	Magnesia.	Alkali.	Loss.	Parts.	Description.
St. Amand,....	75.00	22.10	1.00	0.25	traces	0.84	0.81	100.00	Common body, earthy glaze.
Helsingborg, ...	74.60	19.00	4.25	0.62	traces	1.30	0.23	100.00	Coarse greyish body, ill moulded, glazed with salt.
Voisinlieu,	74.30	19.50	3.90	0.50	0.80	0.50	0.50	100.00	Fine whitish body, well moulded, salt glaze.
Vauxhall,	74.00	27.04	2.00	0.60	0.17	1.06	0.13	100.00	Fine whitish body, well moulded, with a porous external surface, salt glazed.
Freechen,	64.01	24.50	8.50	0.56	0.92	1.42	0.09	100.00	Dark brown body, fine, well moulded, covered with an earthy glaze.

STONEWARE UNGLAZED.

Place.	Silica.	Alumina.	Oxide of Iron.	Lime.	Magnesia.	Alkali.	Loss.	Parts.	Description.
Baltimore,.....	67.40	29.00	2.00	0.60	—	0.60	0.40	100.00	Very fine whitish body.
Wedgwood, ...	66.49	26.00	6.12	1.04	0.15	0.20	—	100.00	Very fine yellowish body, very sonorous, well moulded.
Saveignies,....	65.80	27.64	4.25	1.12	0.64	0.24	0.31	100.00	Clear brown body, coarse, very sonorous.
Japan,	62.04	20.80	15.58	1.08	traces	traces	1.00	100.00	Very fine body, well moulded, of a deep brown-red color.
China,	62.00	22.00	14.00	0.50	traces	1.00	0.50	100.00	Very fine body, well moulded, of a deep brown-red color.

are bricked up during the firing. At Lambeth, near London, the kilns assume a vertical character, are about ten feet in diameter in the baking chamber, and

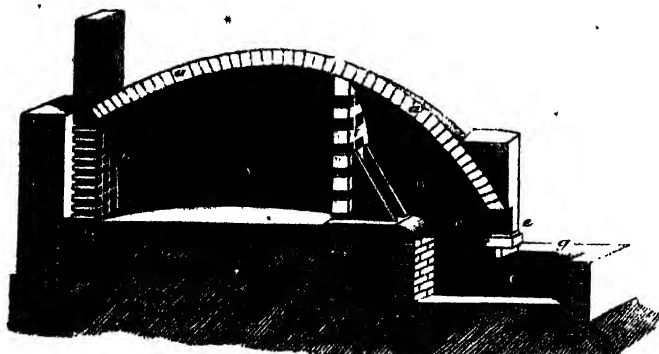
in square cells formed by placing stout tiles upright in rows, with others laid horizontally upon the top—the heavier and coarser portions of the ware

being placed upon the top. These cells or boxes generally occupy one-half the height of the kiln. Great care and experience is required in the management of the fires, as, if too little air is admitted, the smoke and gas will be imperfectly consumed, and the wares discolored; while, on the contrary, if air enters too freely the heat is not sufficiently intense to vitrify the clay. The heat of the furnace often attains 120° Wedgwood, this ware requiring the most intense heat, after real porcelain, of any kind of pottery.

Common stoneware, being sufficiently dense and vitreous in its mass to be impermeable, requires no glaze, but by a very cheap and simple process the dull surface is made smooth and lustrous. A natural glaze, or the waste from other branches of the manufacture, is used, ground to a fine powder, and sifted or sprinkled over the moist ware in a thin stratum; it is afterwards burnt on in the process of firing. Iron slag is generally used for this purpose, the large proportion of the oxides of iron and manganese which it contains rendering it of easy fusion.

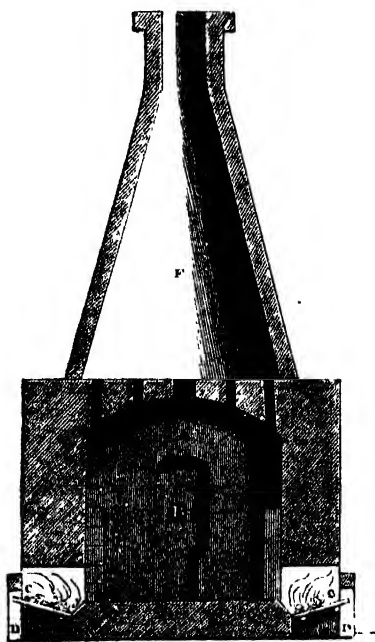
Salt-glaze.—The simple and old-fashioned salt-glaze is also of very general application. Its discovery, dating about the year 1680, is said to have been accidental, the tradition being that at Stanley farm at Bagnall, about five miles East of Burslem, the servant of Mr. JOSEPH YATES was boiling a strong brine of salt, to be used for curing pork; during her temporary absence the liquor boiled over the sides of the earthen vessel used for this purpose, and, becoming very hot, the vessel on cooling had a glazed surface. A Mr. PALMER, who carried on a small pottery about a mile from the farm, availed himself of the hint, and commenced a manufacture of ware glazed with chloride of sodium, which was readily procured from the salt wyes—Middlewich and Northwich in Cheshire. The process of glazing with salt takes place towards the end of the firing, when salt is thrown into the kiln through particular apertures. The temperature of the kiln being considerably above a red heat, volatilizes the chloride into a vapor which, filling the chamber, surrounds the wares, and causes a reaction to take place with the silica of the mass. These two substances, silica and common salt, only act upon each other in the presence of aqueous vapor, and which is always present in the flame of the furnace. With the sodium of the chloride, the oxygen of the water produces soda, which enters into combination with the silicic, while the hydrogen unites with the chlorine, and is evolved as hydrochloric acid— $\text{NaCl} + \text{HO} = \text{NaO} + \text{HCl}$. The glaze is, therefore, a soda glass, and exists as a very thin coating upon the surface of the wares. Clays which contain less than fifty per cent. silica are without action, and do not decompose salt. A brown color is

Fig. 484q.



eleven feet high to the centre of the crown; they have five fire-grates, each twelve inches wide and three feet long, containing five or six fire-bars, a bag or chimney flue about five feet high being placed opposite each fire. Fig. 484r represents a section of one of these

Fig. 484r.



kilns: A is the baking chamber; C the fire-grate; D the ash-pit; and F the bag or chimney, the wares being introduced by the opening, B, bricked up during firing. In the kilns used for common stoneware, the smaller articles are placed at the bottom part of the kiln,

communicated to the wares by throwing into the furnace, during the glazing process, substances which afford a large volume of smoke, such as the bark of the birch tree.

Common stoneware generally varies in color from grey to bluish-grey, yellowish-red, brownish-red, and brown.

The manufacture of stoneware by *moulding*, has recently been brought to great perfection, and most of the vessels used in chemical laboratories are formed in this manner, the smaller articles being remarkably thin and light. The larger vessels for chemical works, such as acid bottles, *et cetera*, are sometimes of enormous dimensions, and constructed to contain from one hundred to three hundred gallons. The agreeable brown color of these vessels is produced by dipping them into water containing oxide of iron in suspension.

The principal seats of the manufacture of common salt-glazed stoneware are at Glasgow, Lambeth, Belper, and Nottingham; the other variety of common glazed stoneware being produced at Bristol and Chesterfield, while the fine stoneware manufacture is almost exclusively confined to the neighborhood of the Staffordshire potteries. On the Continent the manufacture is extensively carried on at several places, particularly at Buntzlau in Silesia, and at Vallendar, on the Rhine opposite Coblenz, where two kinds of clay are worked—a blue clay for grey ware, and a yellow clay for red ware. At Buntzlau the wares are colored brown by immersion into a solution of marly clay after the manner of a glaze.

EARTHENWARE.—Under the term *earthenware* are embraced many varieties of pottery, which in fracture have all an earthy appearance, are perfectly opaque, and are coated with a soft, easily fusible glaze,

containing lead or borax. But, notwithstanding they all possess these characteristics, the modifications and varieties of this ware are more numerous than those of any other kind. The several kinds of clay—plastic or pipe-clay, potters' clay, and marl, to which quartz is sometimes added—enter into the composition of all earthenware. The absence of any real flux, and the circumstance of its being fired at a temperature which precludes the partial or entire fusion of any one of its constituents, distinguishes earthenware from porcelain and stoneware, while the greater care bestowed upon the preparation of the materials, and consequent greater purity of the mass, together with the general absence of color, are sufficient to mark the distinction between this and delftware.

Fine Earthenware.—The English manufacture may be selected as the type of this ware; it is composed essentially of a mixture of plastic clay and quartz, and is, therefore, more refractory, harder, and denser than the delftware, the chief ingredients of which are potters' clay and marl, and which is in consequence soft and calcareous. Fine earthenware again is always coated with a transparent glaze; the commoner sorts with enamel, producing the favorite *Majolica* ware. Neither kinds, however, are fitted for culinary use, as they either split when exposed to heat, or the glaze becomes cracked and crazed.

The crude materials used in England in the manufacture of fine earthenware, are Cornish stone and China clay, a kind of kaolin brought from Cornwall, two varieties of plastic clay, both of which burn white, and chalk-flints. That class called *ironstone china* is made from a mixture of plastic clay, kaolin, Cornish stone in excess, and silica, the formula of which is subjoined:—

IRONSTONE CHINA BODIES.

	I.	II.	III.	IV.	V.	VI.
Cornish stone	180	200	700	600	600	400
China clay	120	150	500	600	100	250
Blue clay	60	100	300	—	180	150
Flint	80	120	250	400	60	75

A small proportion of cobalt blue is added as a stain to whiten the mass.

These are the three principal modifications into which this class of claywares may be subdivided, leaving innumerable others of an intermediate character. Mixtures for the mass of the following varieties are given below:—

FRENCH.

Plastic clay from Montereau and Dreux	87
Quartz	13

ENGLISH.

CREAM COLORED WARE BODIES.

Slip mixtures by measure; Dry mixtures in parts.

	Dry mixtures.			Slip mixtures in inches.		
Blue clay	22	12	11	13	12	12
China clay	9	12	6	3	4	4
Flint	5½	10	4	2	8	8
Cornish stone	—	—	3½	—	—	—

Turquoise Body.

Blue clay	300 lbs.
China clay	175 lbs.
Flint	200 lbs.
Cornish stone	60 lbs.
Turquoise stain	20 lbs.

Turquoise stain consists as follows:—

Blue cobalt	1 lbs.
Flint	2½ lbs.
Oxide of zinc	10 lbs.
Calcined together in earthenware biscuit oven, and finely ground for use.	

Pale Drab Body.

Fine white earthenware body	700 lbs.
Stain—nickel	4 lbs.
Cobalt calx	1½ lbs.

Buff Body.

Finely ground grey marl	100 lbs.
Fine earthenware body	100 lbs.

Inside Wash for above colored bodies.

China clay	40 lbs.
Blue clay	20 lbs.
Flint	20 lbs.
Cornish stone	10 lbs.
Cobalt calx, to whiten	15 drachms.

This wash is poured smartly into the interior of the ware after forming, and immediately emptied.

COLORED CLAYS FOR ORNAMENTATION.

Turquoise or blue, take of the body of the ware 40 lbs., and 1½ lb. of the turquoise stain.

Green Clay.

Body	40 lbs.
Nickel	8 lbs.
Cobalt calx	3 ounces.

Drab Clay.

Body	60 lbs.
Nickel	12 ounces.
Cobalt calx	3 ounces.

Dark Chrome Green Clay.

Body	40 lbs.
Oxide of chrome	8 lbs.

Orange Clay.

Body	40 lbs.
Fine red marl	20 lbs.
Flint	7 lbs.

In general use for moulding and pressing.

FINE EARTHENWARE BODIES.

In *Slip* by measure.

Slip mixtures in inches in tub.

	Ounces to the pint.	I. Inches.	II. Inches.	III. Inches.	IV. Inches.
Blue clay	24	7½	12½	7	9
China clay	26	9	5	9	7
Flint	32	3	3	5½	5
Cornish stone	31½	½	—	2½	3

Dry in parts.

	I.	II.	III.
Blue clay	200	500	500
China clay	200	800	650
Flint	200	800	400
Cornish stone	75	300	200

TERRA-COTTA, OR POROUS BODIES FOR WATER BOTTLES, ETC.

	Green.	Blue.	Red.
Earthenware body	100	100	300
Cornish stone	15	10	100
Oxide of chrome	3	3	Turquoise stain.

	Can.
Grey marl	120
Blue clay	13
Flint	6

The marls should be very carefully sifted through fine lawns, and if ground finely in a pan at the mill, the body will be much improved. This remark applies to all colored bodies.

These porous bodies are all fired in the glazing oven.

Preparation of the Material for forming the Mass.—The flints are prepared for the grinding process by crushing in their calcined state under the stamping-mill—Fig. 484s—which consists of a series of upright beams, *a, a, a*, of wood, shod at their lower extremities with heavy iron shields, *b, b*. These beams being alternately raised in a vertical direction by means of projecting pins, *c, c*, catching the arms of a revolving drum, *d*, fall with great force into a long narrow trough, *f*, placed in a horizontal direction underneath, and having its bottom formed of perforated cast-iron plates, *m*, through the holes of which the broken calcined flints pass, and are then ready to be conveyed to the block-mill.

The mill room where this grinding process takes place is fitted with a number of circular vats—Fig. 484t—from ten to twelve feet diameter; the bottoms of which are paved with square blocks of a very hard stone. These vats are fitted with arms in the same

manner as the mixing vats described under *Portelain*. Blocks of stone weighing from ten to fifteen hundred-weight are placed against the arms, which are driven round by machinery. Into these vats the broken calcined flints are thrown, and water is introduced to prevent the escape of the finer particles of dust, which would be very injurious to the workmen. By this process the flints quickly acquire a state of minute division. After a period of about twelve hours the contents are run off through troughs into washing tubs or vats, where the coarse or heavier particles subside, the fine liquid flint passing into spacious reservoirs built and paved with bricks, and which are furnished with plugs, to enable the workmen to draw off the first water with which the grinding process took place, and bring the flint into a state fit for use.

The *Cornish stone* is brought from Cornwall in masses for the purpose of being ground and prepared, but without the process of calcination, and is used in

the bodies, however, is a most valuable ingredient in the composition of the potters.

The process of grinding *glazes* is similar to that of

flint grinding, but the vats or pans employed are generally of smaller dimensions. The requisite machinery not being erected at all the manufactories, the potters are usually supplied with the materials prepared ready for use, by mills established in the localities where this process is carried on.

A species of stone, which has been termed *Lagnatia quartzite*, and is found in Scotland upon the estate of

Ardsheal, Argyllshire, has been recently introduced by Mr. MILES LOCKHART into the Staffordshire potteries for the purpose of grinding the flint. Being composed almost entirely of pure silica, it is harder and more

room where they are macerated by water, and pass into the tubs, *a* and *b*. The China clay, *a*, is brought to the standard of twenty-six ounces to the imperial pint, and that at *b*, containing the Dorsetshire or blue ball clay, to the standard of twenty-four ounces; the ground flint contained in the trough at *c* is likewise brought to the standard of from thirty-one and a half to thirty-two ounces, while the Cornish stone at *d* is of the standard weight of from thirty to thirty-one and a half ounces to the imperial pint. The China clay and blue ball clay having been admitted into the tanks, *e* and *f*, severally, in the proportions marked upon the gauge rods, *s s*, are united in the mixing cistern, *g*, the blue ball clay passing by the trough, *n*. The relative proportions by measure of Cornish stone and flint are now added, and mixed with the mass, which then passes into the trough, *t*, furnished with plugs and holes, *c' c' c'*, in its bottom, immediately over a set of fine silken sieves, *a' a' a'*, fixed in a frame, *p*, to which a sifting motion is imparted by attachment to the eccentric and rod, *d'*, worked by the engine. This lateral to and fro motion of the sieves cause a complete filtration of the slip into the tank, *h*, all the coarser impurities being left behind. From this tank, *h*, it is conveyed by the pump, *j*, and spout, *k*, into the trough, *e'*, where it undergoes a second and similar process of filtration through finer sieves, falling into the reservoir, *i*, and is conveyed away by the pumping apparatus, *m*, to the purifying machine, and for conversion into slip of the proper degree of consistency for working.

The *purification* of the slip by the abstraction of all particles of iron which have become incorporated with

Fig. 484a.

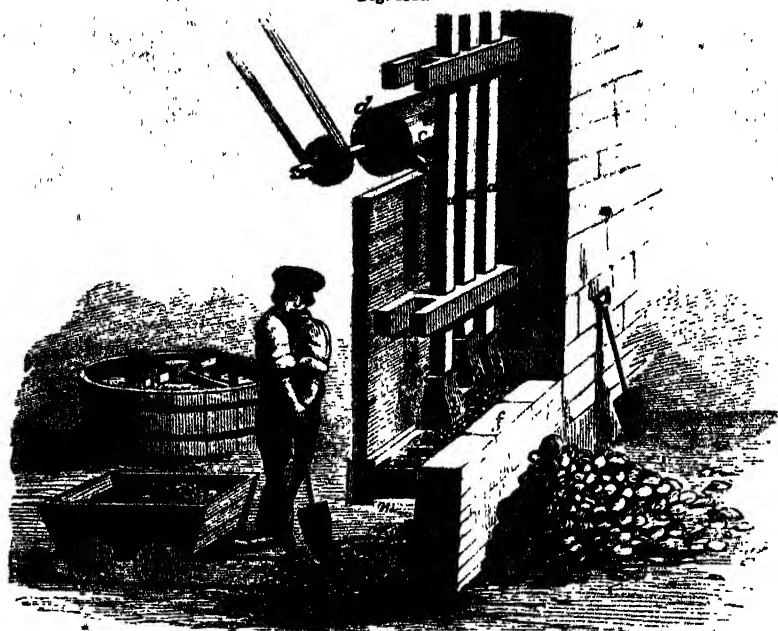
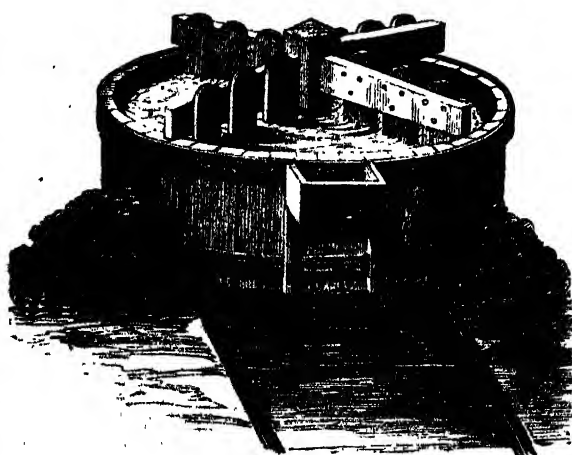


Fig. 484x.



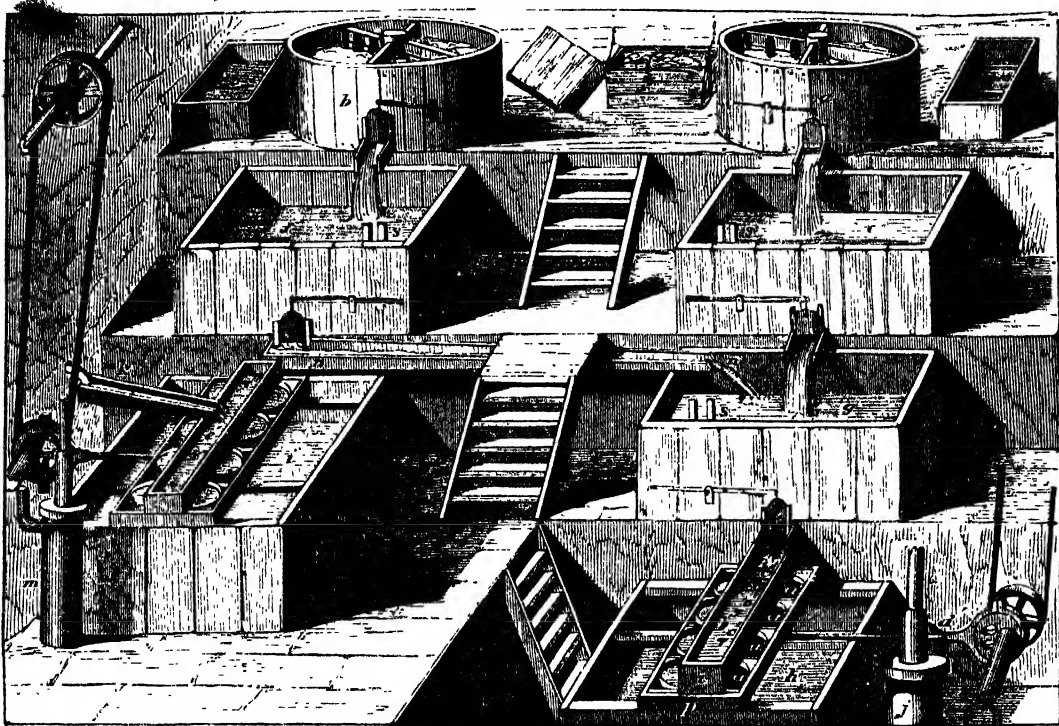
Ardsheal, Argyllshire, has been recently introduced by Mr. MILES LOCKHART into the Staffordshire potteries for the purpose of grinding the flint. Being composed almost entirely of pure silica, it is harder and more

of the proper degree of consistency for working.

it, from the abrasion of the iron hoops of the mill during the process of grinding, is one of great importance,

as were these impurities to pass through the process of firing, the iron, being converted into an

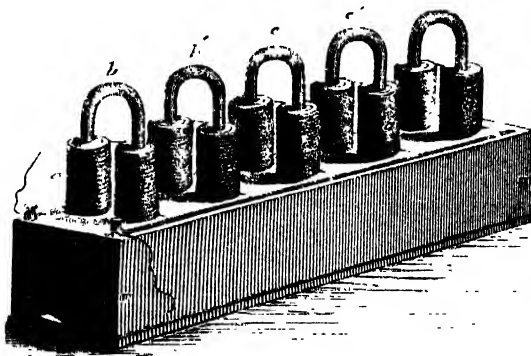
Fig. 484u.



oxide, would produce a brown or yellow stain upon the white surface of the ware. A clumsy and expensive method is frequently used to extract these par-

iron removed—a work of extreme labor and time, in consequence of the electricity of the magnets remaining constant. Greater simplicity, economy, and cer-

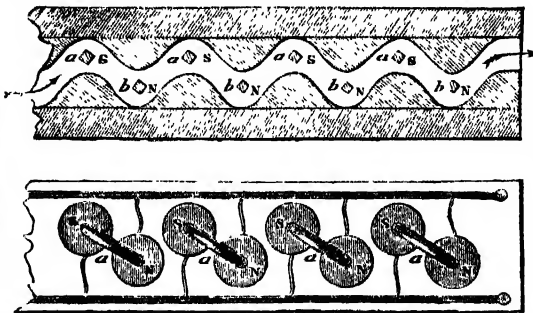
Fig. 484v.



ticles from the mass, by placing in a box a large number of small horseshoe magnets suspended upon a frame. The slip or glaze, as the case may be, is poured by an attendant into the box, and the frame containing the magnets afterwards agitated to bring the slip into contact with them; by this means the iron particles are attracted to the poles of the magnets, which are afterwards taken out one by one from the trough, and the

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Fig. 484w.



tainty have been given to this operation by Messrs. HOLMES and CORDON, who have recently patented an invention which, by the application of electric currents for inducing magnetism in soft iron, effectually purifies the slip or glaze from all such particles in a much shorter time, and at a great saving of expense to the manufacturer. One form of the apparatus is shown at Fig. 484v. *a a a*, are a series of coils inclosing the electro-magnets, *b b', b b', c c', c c'*, the coils being placed in such

5 M

a manner that the induced magnetism in the alternate poles of each set shall be of an opposite nature—Fig. 484w; the arrangement of the North and South poles is shown at *a* and *b*. The slip, in its passage through the machine, comes into contact successively with the several poles of the magnets; and the particles of iron being attracted by them, the slip is thoroughly cleaned from iron by the operation. The apparatus is placed in a strong box, *E*, with two apertures, *r* and *u*, for the passage of the slip through the machine.

The slip, which is now much too liquid, passes into the slip-house for consolidation in troughs of brickwork from eighty to one hundred feet or more in length, and about four feet wide by fourteen inches in depth. The fire, placed at one end, passes by means of flues under the bottom, which is constructed of tiles, into the chimney at the further end, by which means the whole of the heat is economized. The slip, upon reaching the boiling point, throws up a dirty scum, which is scooped off, the tumultuous ebullition preventing the separation of the particles, and securing the uniform mixture of the mass. This process requires about eighteen hours, care being taken to prevent any portion of the mass from burning during the evaporation.

In extensive manufactories where machinery is used, the beautiful apparatus patented by Messrs. NEEDHAM and KITE, for consolidating the slip by pressure, is being introduced, and is a decided improvement upon the old process of evaporation by heat

bolted together by iron clamps, *b b*, in pairs, and forming the mass, *A N*. These separate compartments are each fitted up with a series of small wooden grooves or channels, *d d d'*—Fig. 484y—sunk half an inch below the level of the frame, *a a*, and having a canal or passage, *b b*, cut top and bottom of the passage of the

Fig. 484y.

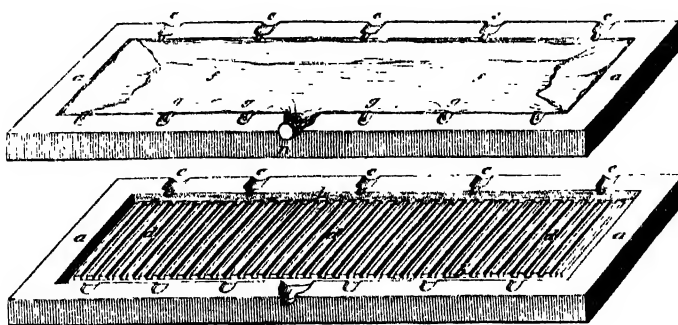
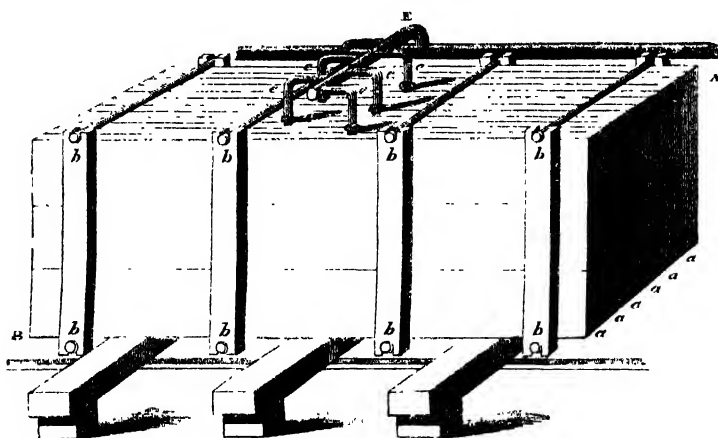


Fig. 484x.



The machine—Fig. 484x—constructed of stout wood, in the form of a rectangular mass, is composed of a series of separate chambers or compartments, *a a a*,

water pressed from the slip through the holes, *c c*. By this arrangement each pair of frames when placed together will have a space between the grooves of one inch, into which the slip is forced by means of the connecting pipes and apparatus, *E*, each pair of frames having its separate supply pipe, *e*. The interior of the chamber is prepared for the reception of the slip by the insertion of a strip of fine hempen cloth, *f f*, the edges being wrapped and folded up to form a large bag, and the nozzle, *n*, for receiving the supply pipe, *e*, being permanently fixed on the double fold of the cloth. The weight of the bag is supported by the

hooks, *g g*, upon the upper portion of the frame. The machine being screwed up tightly by the rods, *b b*, the pressure is brought on by the pumps, and the water passes out through the fibres of the cloth and grooved channels, leaving the slip in the form of a thin, solid, compact, and plastic sheet of clay. The time required for the operation varies from an hour to two hours and a half according to the composition of the mass, the charging and discharging of the machine occupying an hour. Each machine can produce at the rate of four tons of prepared clay in the day. In order to strengthen the fibres of the cloth, and to enable it to with-

stand better the pressure and abrasion of the grooved surfaces of the chambers, it is dipped into a solution containing half an ounce of alum to a gallon of water,

an operation found greatly to increase its durability and resistance to wear and tear. Some statements of the expense and performance of these machines, compared with the old process of evaporation, are given below:—

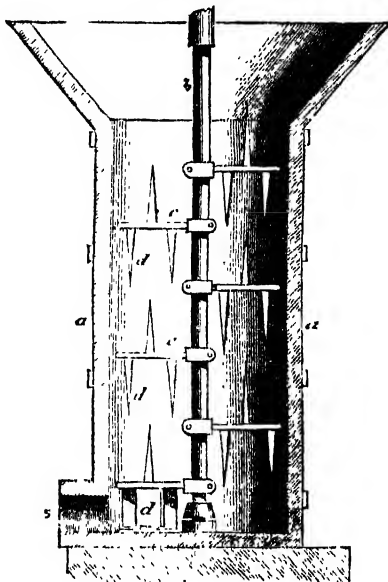
COMPARATIVE COST OF CONSOLIDATING THE CLAY FROM THE SLIP.

By the Old Evaporating Kilns, over a period of six months		By Needham and Kite's patented process, over a period of six months.	
1000 tons clay at 1s. 4d.,	£66 13 4	1000 tons clay at 3s. 6d.,	£175 0 0
Wear and tear of kilns,	32 0 0	Milling, at 4d.,	16 13 4
750 tons coal at 4s. 9d.,	178 2 6	Steam-power,	20 0 0
		Patent right per ton 6d.,	25 0 0
			£236 13 4
		Saving,	40 2 6
	£276 15 10		£276 15 10

The cost of preparing the slip is in each case 8d. per ton.

The slip in this state passes through the *clay* or *pu-y-mill*—Fig. 484z—in order to bring the mass to a

Fig. 484z.

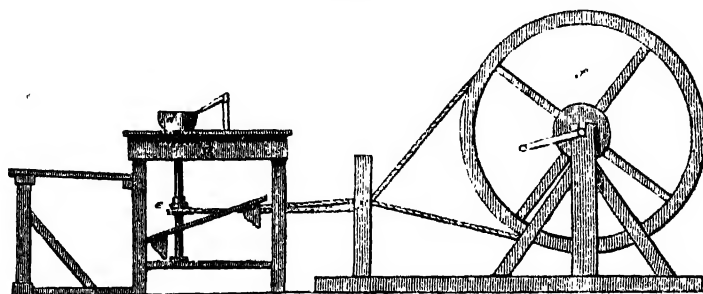


uniform consistency. The mill consists of a circular iron vat or cylinder, *a*, bound together by iron hoops, through the centre of which the iron shaft, *b*, revolves, carrying with it several horizontal arms, *c*, armed with the sharp blades, *d*; these are fixed in a horizontal position, and inclined at a certain angle; by this arrangement the clay in its passage through the mill is cut up and forced out at the aperture, *s*, the mass constantly sinking as it is supplied with fresh clay from above, and separated as it issues from the machine, by means of a fine wire, into blocks, which are carried away to the store house for the process of *aging*—see *Porcelain*. Before the mass is placed in the thrower's hands it under-

goes a further state of preparation, termed *slapping* or *wedging*, by being forcibly thrown upon a strong slab of plaster of Paris. The workman then divides the mass, and the piece cut off is again brought down with considerable force upon the other portion, a continual dividing and slapping of the mass being continued until the whole is of a perfectly homogeneous texture; at the same time care is taken not to cross the mass, but to *slap* the pieces together in the relative position from which they were cut, as, if this precaution were not observed, the ware would afterwards contract unequally in the firing. From twenty to twenty-five blows are given to the mass before it is sufficiently homogeneous for manufacture.

Throwing.—From the much greater plasticity of the mass used for earthenware, the operation of throwing upon the wheel is one of greater rapidity than is the case with the manufacture of either porcelain or stoneware, an experienced *thrower*, assisted by two boys, often producing as many as from twelve hundred to fifteen hundred eight-inch basins in a working day of ten hours; while between two thousand and three thousand of the small round ink bottles may be produced in the same time by a lad and his assistant. This extreme facility in the manipulation is certainly one of the principal reasons for the low price of the ware. The potter's lathe, in its general form, where machinery is not employed, is shown at Fig. 484AA, and consists of a fixed table, *a*, carrying an upright shaft, *b*, to which the *throwing* disc or head, *d*, is fixed for receiving the

Fig. 484AA.



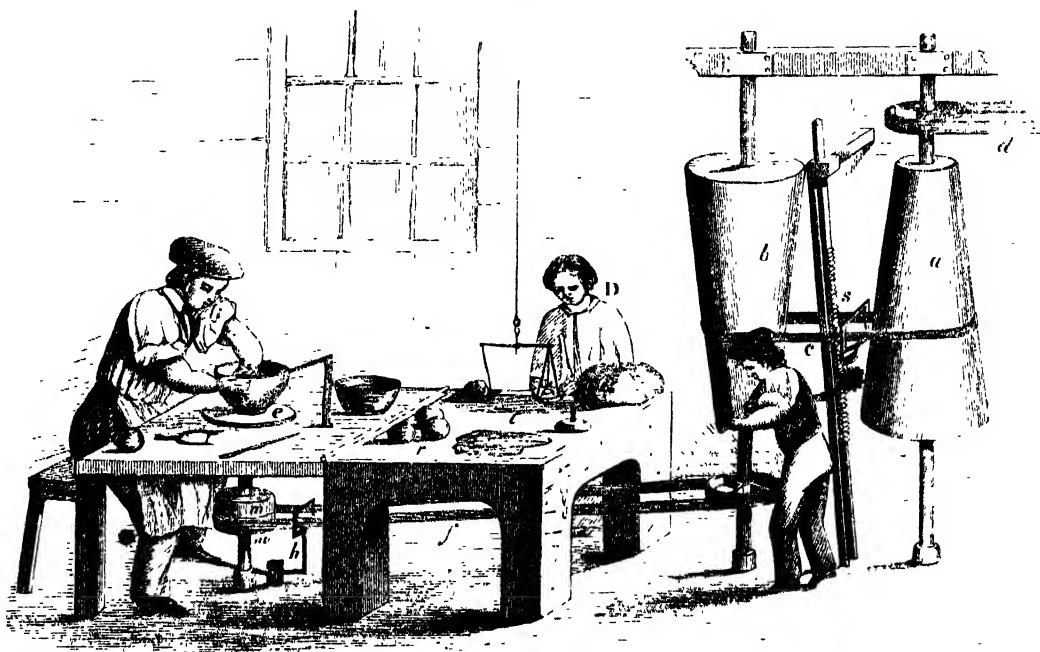
mass of clay. *c* is a pulley fixed on to the shaft with grooves of different diameters, and receives motion from the driving wheel, *f*, by a cord passing under the

guide pulley upon the frame, *g*. The workman, seated upon the bench, *h*, regulates the velocity of his disc in the shaping of the mass by corresponding signals to the assistant who turns the wheel, *f*.

In the manufactories of WEDGWOOD and COPELAND, the lathes are driven by engine power, the arrangement

for regulating the speed, *et cetera*, being shown at Fig. 484BB. *a* and *b* are two conical drums, connected together by the belt, *c*, and to which motion is communicated by the driving wheel, *d*. The thrower sits at his table, and the axle, *e*, carries the disc, on which are placed two pulleys, *m*, *n*, one fixed, the other loose,

Fig. 484BB.



in connection with the drum, *b*, by means of the strap, *f*. The revolution of the lathe is thrown off and on by the treadle, *h*, under command of the operator's foot. The speed of the lathe is regulated by the assistant, who elevates or depresses the belt, *c*, upon the drum, *b*, by means of the winch and carrier, *s*, through which the strap works.

The *baller*, who prepares the mass for the *thrower*, is shown at *D*. Each piece is weighed when the vessels require to be of a uniform size, a stroke or two of the hand being given before it is pressed into the balls, *r*, ready for use by the thrower, who, after the formation of the vessel, dexterously separates it at the base from the disc by a fine brass wire, and places it on a board, where it remains until the mass becomes sufficiently firm to bear without injury the subsequent processes of turning, handling, *et cetera*.

Turning.—This manipulation requires considerable dexterity on the part of the workman, to avoid destroying or fracturing the piece whilst turning it to the requisite size, thickness, and shape, and presents also numerous opportunities for the exercise of skill, taste, and genius in giving to the several parts the prominence required, and to the whole the degree of elegance suggested by the pattern.

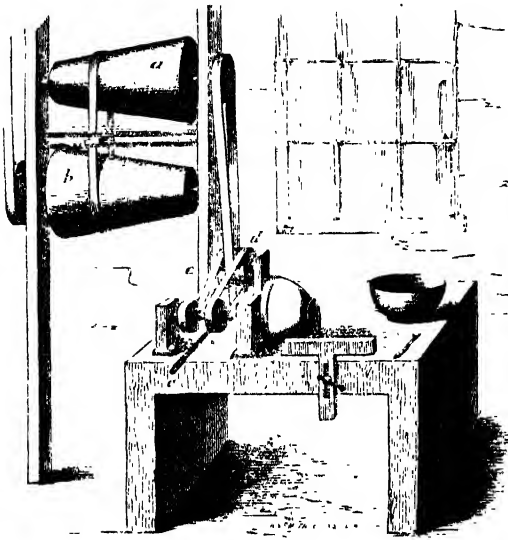
The common horizontal lathe resembles that in use for wood turning, and is generally set in motion by

male or female assistants, who by practice become remarkably apt in adapting the velocity of the motion to the requisitions of the turner, and at the same time perform all the necessary attendant operations, such as stamping the goods, and bringing them to or from the lathe. The vessels are fixed upon the head-stock of the lathe by insertion upon a chuck of a tapering form, which easily adapts itself to the inner surface of the vessel. The engine-lathe, turned by steam power—Fig. 484CC—has the speed regulated by the gauge, *b*, shifting the position of the band upon the driving drum, *a*. The motion of the lathe is reversible by the lever, *c*, changing the position of the driving belt from the direct motion pulley, *d*, to that of the reversed one, *e*. This retrograde motion is required for the final operation of smoothing, solidifying, and polishing the vessel after turning.

The turner's tools are of iron, thin, and well forged, about eight inches in length, and varying in breadth from a quarter of an inch to two inches, the cutting end being turned up at a right angle about half an inch, and made sharp and level upon the grindstone. All wares that are not circular in section, and such as are ornamented with bas reliefs, are made in plaster moulds, into which the mass is pressed with a sponge, *et cetera*. Thin vessels are made at the wheel, with the assistance of plaster moulds and tools, as already

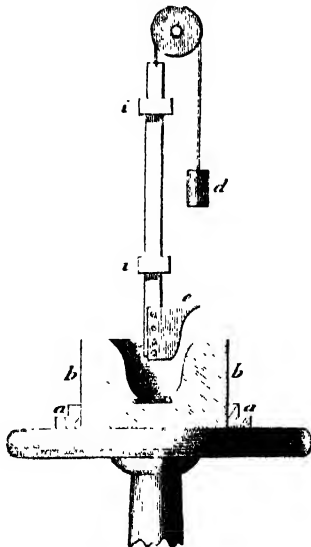
described. When simple forms are required in great quantities, the hand of the moulder has lately been replaced by machinery, more particularly in some of the Northern potteries about Glasgow, Newcastle-upon-

Fig. 484cc.



Tyne, and Yorkshire. Fig. 484DD represents a form of the apparatus in which the cups are formed by means of the plaster mould, *b*, giving the exterior form, while

Fig. 484DD.

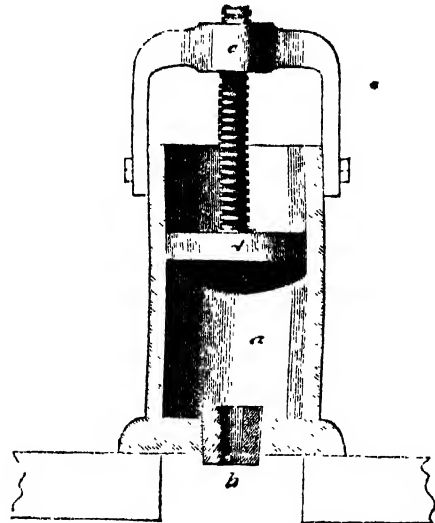


the tool, *e*, gives the interior shape. The plaster mould is fixed in its proper position upon the head of the disc by the iron ring, *a a*, in such a manner that its centre corresponds exactly with the point of the tool. The mould is brought into revolution by means of a treadle, while the tool, *e*, counterpoised by the

weight, *d*, is lowered to the proper distance through the guides, *i i*, by means of a second treadle. When a ball of clay is placed in the mould, and the treadles moved, the tool, *e*, descends into the revolving mass of clay and bores a hole, forming a cup, the thickness of the sides of which will correspond to the distance at which the tool, at its lowest point, is separated from the sides of the mould. When the forming is finished, for which a few seconds suffice, the treadles are set at liberty, and the mould brought to a state of rest; the tool being raised up above the mould by the weight of the counterpoise, *d*. The mould, with the finished piece, is then exchanged for another, and the operation repeated. A machine of this kind can be worked by female labor at a less cost than that of experienced moulders.

Handling, et cetera.—These manipulations are performed, for the better class of wares, by moulding in the same manner as that described under *Porcelain*, while for handles of a less ornamental nature, recourse is had to a small machine, called the *squeezing box*. This consists of an iron cylinder, *a*—Fig. 484EE—about six inches in diameter, and twelve inches deep, the

Fig. 484EE.



bottom of which has a hole, into which a piece of lead, *b*, is inserted, pierced of the size and section of the intended handle. The upper edge of the cylinder carries a strong iron frame, *c*, into which works a screw plunger, *d*; this, upon depression, forces the clay through the aperture in stripes of the proper form, and which afterwards, when cut into lengths and bent as required, are left to acquire their proper consistency before application to the wares. In this operation the handler cuts away from the edges or ends all superfluous clay, and, after moistening with slip the parts of contact, presses them gently against the body of the ware; they are afterwards trimmed with the knife to remove all superfluous matter. The vessel is then rubbed over with a moist sponge to remove all dust, previous to drying and placing in the seggars for the baking process.

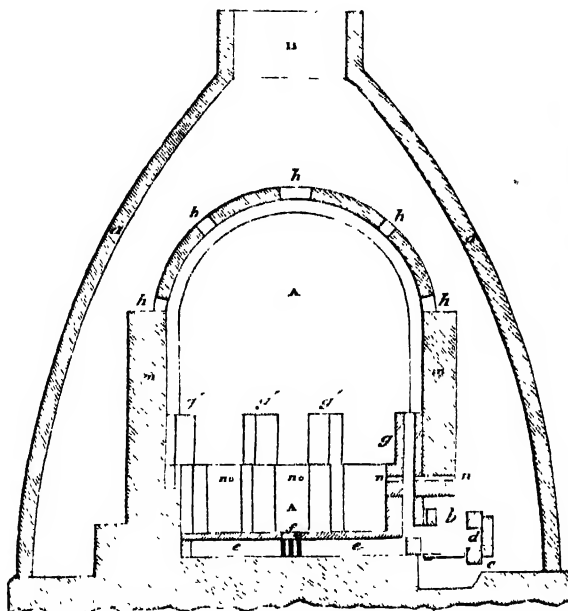
Pressing, or hollow-ware squeezing, is a more laborious manipulation connected with this branch of manufacture.

The clay having been prepared by beating with the bat upon the gypsum slab to the proper thickness and dimension, is placed upon one of the sections of the mould, and with a moist sponge well worked into every part. All the sections being thus lined with clay, the edges are trimmed, and the parts of the mould carefully placed together, and secured in their position by a strap passed round them. The presser then passes his finger up every joint, so as to make a groove, into which a thin roll of clay is inserted, and worked into the mass by the finger, and smoothed with moist leather. All marks are removed with a sponge moistened with slip, and the inside is afterwards washed with clean water and a sponge. The mould and its contents are then set aside until firm enough to receive polish with a flexible horn plate. The article is afterwards removed from the mould, trimmed and polished with proper tools, to remove all appearance of seams, and the handle, spout, or other ornamentation, added in the usual way before baking. One mode of decoration which may be here described consists in the formation upon the ware, while in the lathe, of rings and devices in various colors. This decoration is produced in different ways. When an inlaid pattern in various hues, the workman, while the ware is in the plastic state, and revolving upon the headstock of the lathe, impresses the pattern upon the surface by a roulette, and afterwards blows through a fine tube, out of a bottle, thick colored slips into the several sunk parts, the bottles containing the slip being furnished with a mouth-piece and tube for that purpose. The surplus colored clays being afterwards turned off in the manner described under *Fine Stoneware*, the various inlaid rings of color are produced. When a marbled appearance is required, the tinted mixtures are placed in separate compartments of one vessel furnished with a spout in connection with the several chambers. On their exit from the vessel, all the colors flow out in a single stream, but unmixed with each other. This stream flowing upon the ware causes a waved or variegated appearance according to the regularity of the motion given to the piece, and articles so decorated, are commonly termed *deppel* and *mocha* ware. All these colored clays require to be in the *slip* state, and not of an oily nature. The wares are afterwards fired and glazed as usual, according to the nature of the operation has been performed while in the plastic or biscuit state. A pleasing arborescent effect is sometimes given to these wares by a mixture of tobacco water, with manganese, nickel, oxide of iron, and a small quantity of cobalt, dropped on to the soft colored slip surface of the ornamentation.

Firing.—The temperature at which fine earthenware is baked being much higher than that required for the glaze, renders it necessary that vessels composed of this substance should be fired twice. At the first firing

the ware is completely baked, or converted into biscuit, the glaze only being burnt on in the second firing. Two separate furnaces are employed for these distinct operations. The kiln used for baking—Fig. 484FF—has only one chamber, A, and is surrounded by a

Fig. 484FF.



conical brick building, *aa*, termed a *hovel*, that serves at once the purpose of roof and chimney. The construction is nearly the same as that of an upright reverberatory furnace, differing from the porcelain kiln by a better arrangement for the distribution of the flame, and the use of coal for firing in place of wood. The draught is regulated by the aperture, *b*, and passes into the furnace in a downward course, carrying with it the flames in a horizontal direction; *c* is the opening for removing the cinders, and *d* that by which fuel is introduced into the furnace. The flame, before entering the chamber of the furnace, is divided; part of it retaining its original direction, passes through channels below the sole of the furnace, along the horizontal flues, *e*, and enters at the central point, *f*, the remainder circulating upwards through the small chimneys or bags, *g*, situated against the wall, *m*, of the kiln, A. Each fire, of which there are six or eight, has a corresponding chimney, *g' g'*, and horizontal flues converging towards *f*, and becoming narrower as they approach the centre. The flame finally escapes through the openings, *h h h*, in the dome of the chamber, A, and out of the top of the hovel, B. The small openings, *n n*, are for the removal of the *watches* from the seggars placed opposite, and by which the potter ascertains the state of the kiln. The height of the chamber, A, averages about eighteen feet, the diameter about sixteen feet.

It being generally the custom, in the manufacture of fine earthenware, to prepare several kinds of goods

at the same time, care is taken in the firing to place those wares, such as ironstone china, *et cetera*, that require the greatest amount of heat, in the hottest portion of the kiln. As has already been stated, no kind of earthenware can withstand the direct action of the flame, especially that from a coal fire; the wares are, therefore, always inclosed in seggars, while the comparatively low temperature at which the wares are baked admits of a great economy of space, the individual pieces being packed closely. The seggars are

arranged in the kiln in columns or bungs after the manner described under *Porcelain*. The temperature of the biscuit kiln ranges from 90° to 100° Wedgwood. The following tabular statements will show the approximate number of bungs and seggars contained in the biscuit kilns at each firing. It must, however, be observed, that the bracket mentioned in the table is not general throughout the Staffordshire Potteries, but has been successfully used for many years by Messrs. COPELAND in their kilns:—

No. 1.—LARGE OVEN—Dimensions, 18 feet diameter; 17 feet 6 inches high.

Bracket,.....	containing 39 bungs	of ovals,.....	13 high, or 507 seggars.
Arches,.....	" 8	" 16 in. ovals	22 " or 176 "
First ring,.....	{ " 15	" ovals	
	{ " 8	" 14 in. "	26 " or 624 "
	{ " 1	" 16 in. "	
Second ring,.....	{ " 3	" 20 in. 23 high	
	{ " 5	" 18 in. 23 "	
	{ " 1	" 16 in. 24 "	or 312 "
	{ " 1	" 14 in. 26 "	
	{ " 3	" ovals 26 "	
Third ring,.....	{ " 5	" ovals 30 "	
	{ " 1	" 18 in. 28 "	or 336 "
	{ " 4	" plates 37 "	
Middle ring,.....	{ " 3	" ovals 31 "	
	{ " 1	" 14 in. 30 "	or 237 "
	{ " 3	" plates 38 "	
Number of bungs,.....		101	
		Number of seggars,.....	2182

No. 2.—SMALL OVEN—Dimensions, 15 feet diameter; 14 feet 6 inches high.

Bracket,.....	containing 40 bungs	of ovals,.....	13 high or 520 seggars.
Arches,.....	" 8	" 16 in. ovals.....	24 " or 192 "
First ring,.....	{ " 20	" ovals	
	{ " 5	" 14 in. ovals	29 " or 725 "
Second ring,.....	{ " 2	" 20 in. ovals 22 high	
	{ " 5	" 18 in. ovals 23 "	
	{ " 1	" 16 in. ovals 23 "	or 234 "
	{ " 2	" ovals 26 "	
Third ring and middle,.....	{ " 1	" 16 in. ovals 26 "	
	{ " 1	" plates 34 "	
	{ " 4	" ovals 27 "	or 220 "
	{ " 2	" 14 in. ovals 26 "	
Number of bungs,.....		79	
		Number of seggars,.....	1444

No. 3.—LARGE OVEN—Dimensions, 18 feet diameter; 17 feet 6 inches high.

Bracket,.....	containing 40 bungs	of ovals,.....	13 high or 520 seggars.
Arches,.....	" 8	" 16 in. ovals.....	24 " or 192 "
First ring,.....	{ " 20	" ovals	
	{ " 5	" 14 in. ovals	29 " or 725 "
Second ring,.....	{ " 8	" 18 in. ovals 29 high	
	{ " 2	" 20 in. ovals 29 "	
	{ " 3	" ovals 32 "	or 386 "
Third ring,.....	{ " 9	" ovals 33 "	
	{ " 2	" plates 41 "	or 379 "
Middle ring,.....	{ " 5	" ovals 34 "	
	{ " 1	" plates 42 "	or 212 "
Number of bungs,.....		103	
		Number of seggars,.....	2414

The mode of constructing the *seggars* for firing the fine earthenware is shown at Fig. 484gg. The marl, after beating out by the bat, *a*, upon the iron or stone slab, *b*, is cut to the required height of the seggar, and wrapped round the wooden drum or shape, *c*; the necessary thickness of clay to form the bottom of the seggar having previously been placed on the wooden shoard, upon the whirler, *d*, the workman now unites

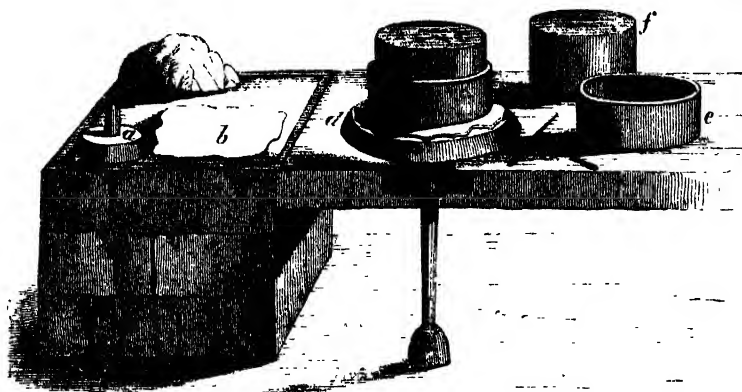
the edges of the sides together by moisture and subsequent kneading of the fingers; the bottom mass is also trimmed round, and luted up into the side in the same manner, the operation being assisted by the rotatory motion imparted by the left hand to the whirler, *d*. The seggar, after the withdrawal of the drum, is shown at *e*, and the drum at *f*. The composition forming the mass of the seggars is as follows:—

Various grey and black marls from the coal-beds mixed together with the addition of from twenty to twenty-five per cent. of coarsely-crushed old biscuit

seggars, these proportions depending upon the plasticity or porousness of the marls used.

In firing earthenware, that quality of coal is selected

Fig. 484nn.



which produces a long flame, and is not of a caking character. The heat is moderated at first until the furnace and its contents have gradually been raised to a red heat; the temperature is then increased, the draught entering from below, and regulated by the opening or closing of the lid. The state of the biscuit is ascertained by the introduction of hollow balls of red clay, bored through on two sides, to enable their removal from the kiln—the degree of color produced affording a clue to the state of the furnace. These balls or watches become first pale-red, and after passing through several tints become red-brown; at which stage those varieties of earthenware equal in quality, or nearly allied to *iron-stone* ware, are sufficiently fired. The softer varieties are fired when the tests appear slightly tinged with dark-red. The firing in the biscuit kiln occupies about forty to forty-eight hours, the average amount of coal consumed varying from fourteen to eighteen tons, according to the size of the kiln.

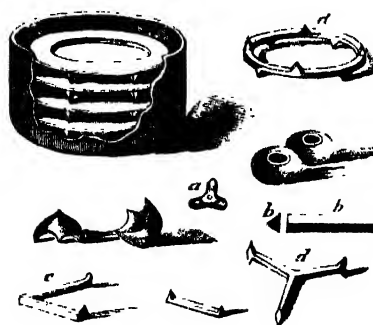
The kilns employed for the after-operation of glazing are of the same construction, but somewhat smaller than the biscuit kiln; the temperature of the furnace for burning the glaze being ascertained by the introduction of balls of clay, previously coated with glaze, into the chamber, and which assume progressively the same changes of color with the heat of the furnace. Frequently the trials from the most successful bakings are preserved in order to use them for the purposes of comparison in future operations of the same kind.

Flat pieces, such as plates, *et cetera*, are separated from each other in the seggars by small pointed supports or rests, made of hard baked clay or earthenware, called *cockspurs*, *stilts*, *triangles*, *et cetera*, as shown in Fig. 484nn; those as *a a*, *b b* being fixed into separate holes made in the side of the seggars, the plate resting upon the edges of the prominent portion, rim downwards, or, as is the case with hollow

wares, separated one from the other by the triangle *c* or *d*.

The extent and importance to which the earthenware and pottery manufactures of England have risen,

Fig. 484nn.



can only be estimated by taking the approximate returns of material used and goods manufactured over a given time, in one of the principal localities—such as the Staffordshire potteries—and which may be taken as follows:—

The total quantity of *pottery material*—such as Cornish stone, flint, kaolin, china clay, pool clay, felspar, *et cetera*—used in the various departments of manufacture in the Staffordshire potteries, during the year 1859, is estimated at not less than two hundred and twenty thousand tons; the manufactured ware sent out of the district during the same period, reaching over one hundred and ten thousand tons, which, taken at an average value of twenty-five pounds per ton, will give the enormous sum of two millions five hundred thousand pounds sterling.

Glaze.—In the composition of the glaze the following materials are used in greater or less proportions:—
 Cornish stone, flint, sand, borax, soda, tinical, white lead, crystal glass, minium, litharge, white lead, lime, china clay, carbonate of lime, smalt; which differ considerably, partly on account of the variable nature of the body, and partly according to the requirements of the ware, whether white, printed, or painted. The glaze is, however, always white, and contains lead, alumina, and soda. Minium and the preparations of lead exert a softening action, while the oxide of cobalt, used in very small proportions, rarely exceeding one-thousandth part, is for the purpose of imparting a delicate blue tinge to the glaze, and counteracting the yellow color of the body of the ware. The essentials of a good glaze are transparency, absence of color, sufficient hardness to resist abrasion, and the property of expanding by heat in nearly the same ratio as that of the body of the ware. The various ingredients are mostly fused together or fritted, and afterwards ground, sieved, and purified, as described, to free the slip from iron to form the glaze. When melted with borax or boracic acid and soda, it is a perfectly transparent green color; with tinical it is impure in color, and of a dirty-brown. The preparations of lead do not always enter into the composition of the frit, but are added to the glaze in the grinding process, with the stain also finely ground. These materials being formed into a thin water fluid, the process of glazing is the same as that described under *Porcelain*. Subjoined are several mixtures for glazes:—

RAW GLAZES.

Common Cream Color Glaze.

Cornish stone	150
Flint	85
Borax	4
White lead	300

Rockingham Glaze.

No. 1.

Red lead	42
Cornish stone	6
Flint	4
China clay	4
Manganese	6

Ground finely for use.

No. 2.

White lead	60
Cornish stone	6
Flint	18
Red marl	6
Manganese	10

Ground finely for use.

No. 3.

Red lead	100
Cane marl	2
Cornish stone	15
Flint	20
Manganese	15

Ground finely for use.

Yellow or Saffron Glaze.

Underglaze yellow color	10 lbs.
White lead	20 lbs.

Very finely ground.

Add to which 20 quarts of cream color glaze—4½ lbs. per quart—well sifted together.

Chrome Green Glaze.

Chrome oxide—green	3 lbs.
Flint glaze	4 lbs.

Ground for stain.

Add to which 48 quarts of printed glaze—28 oz. per pint—and well sift together.

Desert Green Glaze.

No. 1.

White lead	3 lbs.
Calcined copper	3 lbs.
Flint glaze	14 lbs.
Flint	2 lbs.

Finely ground together. And mix—

Of the above	4 quarts.
Printed glaze	12 quarts.
Cream color, ditto	9 quarts.
Earthenware slip	8 pints.

Well lawned together.

No. 2.

Calcined copper	10 lbs.
Cobalt calx	1 lb.

Ground for color.

White lead	23 lbs.
Flint	15 lbs.
Blue clay	3 lbs.

Ground finely.

And to the above compounds add—

Printed glaze	36 quarts.
Cream color glaze	36 quarts.

No. 3.

Calcined copper	3 quarts.
Ground finely; 29 ounces per pint.	
Cream color glaze	20 quarts.
39 ounces per pint.	
Printed glaze	10 quarts.
29 ounces per pint.	

Black Glaze.

No. 1.

White lead	50
Cornish stone	20
Flint	10
China clay	7
Manganese	10

Ground for dipping.

Body as for lustre body.

No. 2.

Red lead	25
Cornish stone	10
Flint	5
Red marl—sifted	5
Manganese	2

Ground as before.

No. 3.

Cream color glaze	20 quarts.
2½ pounds per pint.	
Cobalt blue	6 lbs.
Dark red or lustre body to be used with this glaze.	

Royal Blue Glaze.

The same glaze, used upon white body, produces a fine royal blue glaze.

For lighter tints, according to the quantities of stain employed.

FRTTED GLAZES.

Cream Color Glaze.

	I.	II.	III.	IV.
Cornish stone	180	200	—	80
Flint	60	50	50	80
Flint glass	50	75	50	—
White lead	600	850	200	300
Frit	—	—	100	—
China clay	—	—	—	45
Whiting	—	—	—	45
Frit composed of Cornish stone	20	Calcined in		
Frit composed of soda	1½	glass oven.		
	1	1	5	2

PAINTED WARE GLAZES—FRITTED.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Cornish stone	100	180	80	90	40	50	120	100	120
Felspar	—	—	—	—	40	—	—	—	—
Flint	60	100	70	5	—	35	70	20	80
Lynn sand	—	—	—	—	80	—	—	—	—
Whiting	25	—	—	—	—	40	30	30	80
Chalk	—	—	25	—	15	—	—	—	—
Tincal	—	120	—	—	—	—	—	—	—
Borax	70	—	75	65	60	100	75	60	120
China clay	10	10	—	25	—	30	10	—	30
White lead	60	—	—	—	—	—	—	—	—
Red lead	—	—	—	—	—	—	30	—	—
Soda	—	—	—	25	—	—	10	15	20

Fritted in kiln, and mixed as follows:—

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Cornish stone	60	—	100	150	160	35	75	100	180
White lead	60	100	100	200	160	45	60	—	120
Whiting	—	80	—	80	—	—	—	—	—
Flint	—	—	—	80	—	35	—	—	70
Frit	500	300	300	180	300	240	500	300	300

Others as follows:—

	Frit.	
	I.	II.
Cornish stone	100	100
Flint	—	75
Whiting	50	35
Dorate of lime	150	100
Soda	25	—
China clay	25	15
White lead	25	30

Fritted in kiln, and mixed as follows:—

	I.	II.
Cornish stone	150	35
White lead	100	60
Flint	50	30
Frit	300	250

Another glaze as follows:—

Felspar	30	Boracic acid	35
Flint	20	Soda	35
Whiting	20	China clay	15

Fritted in kiln, and mixed as follows:—

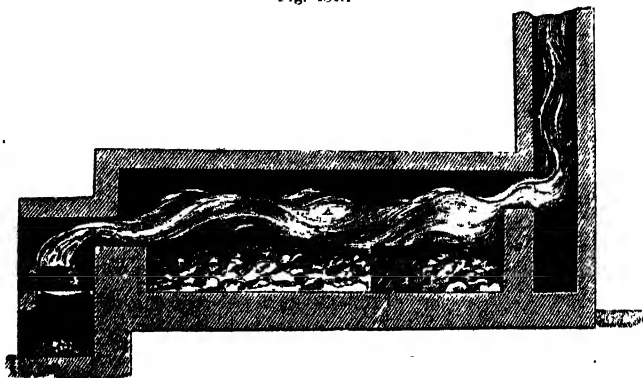
White lead	120	Felspar	150
Whiting	40	Frit	60
Flint	60		

To every charge of 600 pounds weight of the above glazes, about three ounces of cobalt blue are mixed to stain, but varied according to the color of the body.

Drab, turquoise, buff, and other fancy bodies, are dipped into glaze, such as are here given; or sometimes into mixed glazes, varying between the common and the best.

The furnace for preparing the frit is shown at A—Fig. 484II. *a* is the fireplace, the flames passing over

Fig. 484II



the bridge, *b*, into the body of the furnace, *A*, where they are reverberated upon the surface of the fritted

mass, *f f*, and finally escape over the bridge, *c*, into the chimney, *d*. The frit is withdrawn from the kiln in its molten condition by the opening, *e*, and thrown or run into cold water. This aperture likewise serves for the recharging of the oven, and is closed during firing.

When the dipped biscuit has become sufficiently dry, the glaze is burnt in, being placed in seggars similar to the biscuit seggars, and glazed on the inner surface, to prevent absorption during firing of a portion of the basic ingredients of the glaze, particularly oxide of lead, by which the glaze upon the ware would be rendered rough and deficient in lustre. The pieces are separated from each other by contrivances similar to those already described under *Firing*. The marks caused by the points of contact are easily discernible in the earthenware of commerce. These little inequalities are afterwards removed by females from the ware by sharp steel dressing-tools. The junction of every two seggars in the *bung* is luted with clay to make a perfectly secure mass.

Firing.—The time occupied by the firing of the gloss or glaze kiln is about sixteen hours, and consumes from five to seven tons of coal, according to the size of the kiln, the temperature of which is ascertained by the progressive changes in color assumed by balls of red clay coated with glaze, and introduced for that purpose; but it is usual to preserve these trial balls from the most successful firings for comparison in future operations of the same kind.

Printing.—Although, from the nature of the body, it would be inappropriate to devote the same expense to the decoration of earthenware as to that of porcelain, the former very generally receives ornamentation either with the brush or by printing, and is likewise to a great extent decorated with metallic lustres. The process of printing consists of two parts—first, the production of an impression upon thin paper in a suitable ink, and then transference of the ink upon this paper to the surface of the biscuit. The vehicle which serves as the preparation for embodying the necessary colors, is a composition formed of boiled

linseed oil, resin, tar, and oil of amber, and which becomes, when mixed with the colors, sufficiently liquid for use by spreading out upon a hot iron plate. In the selection of tints, those only must be chosen which, in chemical properties, are compatible with the character of the glaze, the temperature of the kiln, *et cetera*. Cobalt blue, manganese black, and chromium green, are very common colors, and then various proportions of these, generally incorporated with the ink for the following colors, are here given:—

UNDERGLAZE, PRINTING, AND PAINTING COLORS FOR EARTHENWARE.

Yellow.

Lead and tin ash .. 4 parts.	{	Mix well together, and calcine at a gentle heat in a glazing oven; to undergo a second calcination at a higher temperature in the same oven.
Antimony .. 1 part.		

Orange.

Antimony .. 3 lbs.	{	Calcination as above.
Litharge .. 3 lbs.		
Lead and tin ash .. 1 lb.		
Ochre calcined .. 3 oz.		

Fine Brown.

Chromate of iron .. 1	{	Calcine only once.
Chromate of lead .. 3		
Calcined sienna .. 2		
Oxide of zinc .. 3		

Brown.

Oxide of manganese .. 4 lbs.	{	Well calcined.
Green oxide of chromium 1½ lbs.		
Cornish stone .. 4 lbs.		

Yellow Green.

Flint glass .. 4 lbs.	{	Calcined at biscuit oven heat, and well pounded, washed with boiling water until clear, and calcined a second time.
Whiting .. 2½ lbs.		
Green oxide of chromium 1½ lbs.		

Yellow Green.

Green oxide of chromium 3 lbs.	{	Calcined together.
Yellow color .. 3 lbs.		
China clay, burnt at biscuit heat .. 2 lbs.		
Fine sand .. 2 lbs.		

Blue Green.

Green oxide of chromium 10	{	Calcined together in biscuit oven.
Oxide of cobalt .. 2		
Flux composed of equal parts of borax and flint .. 15		

Rose Color Pink.

Oxide of tin .. 2½ lbs.	{	Calcined in biscuit oven.
Whiting .. 1 lb.		
Green oxide of chromium ½ oz.		
Cornish stone .. 6 oz.		

Purple.

To 15 pounds of rose color pink add 1 pound of cobalt calx and 1½ pounds of fine sand. These proportions may be varied according to tint required.

Black.

Oxide of chromium .. 6 lbs.	{	Calcine in glazing oven.
Calcined manganese ore 9 lbs.		
Cobalt calx .. 7 lbs.		
Gold litharge .. 10 lbs.		

Black.

Calcined chromate of iron .. 12	{	Calcine together.
Cobalt calx .. 1		

Blue for flowing.

Black prepared oxide of cobalt 12 lbs.	{	Calcine in glazing oven.
Flint glass .. 4 lbs.		
Oxide of zinc .. 2 lbs.		

The above for strong color, to be reduced for weaker tints by a flux composed of equal parts of flint glass and flint.

Blue for ordinary printing.

Blue cobalt calx .. 1 lb.	{	Grind for use.
Cornish stone .. 1½ lb.		

Or a mixture of half stone and half flint.

May be reduced to 1 part of blue and 5 parts of fluxing material. The fluxing of these blues are much varied by manufacturers.

Of late a manufacture has been introduced of a *flowing blue* and other colors, giving a softness to the coloring upon fine earthenware, which has been much esteemed. This is produced by what is termed a *flow*, introduced into the seggar or fire-case; a few of the *flows* are here given:—

Quick lime .. 5	{	Well mixed together and sprinkled carefully round the bottom edge of the seggar.
Salt .. 2		
Nitre .. 2		
Borax .. 4		

Again—

Whiting .. 4	{	Mix and use as above.
Salt .. 2½		

Again—

Nitre .. 4	{	Mix and use as above.
Salt .. 1		
Bone .. 13		
Alum .. 1½		

Again—

Quick lime .. 25	{	Mix and use as above.
Chloride of ammonium .. 2½		
Red lead .. 5		

These and various other mixtures are introduced for the like purposes.

But the most admired is the *pink color*, obtained from acid stannate of oxide of chromium, with stannate of lime, and very extensively applied to decoration. This pigment, originally a profound secret, has been chemically decomposed by MALAGUTI, from the results of which analysis, a practical mixture has been prepared with great success, more especially at Montereau in France. Analysis gave—

Oxide of tin—Sn O ₂ ..	78.31
Lime ..	14.91
Silica ..	3.96
Alumina ..	0.95
Water ..	0.61
Oxide of chromium ..	0.52
Chromate of potassa ..	0.26
Potassa and loss ..	0.48

100.00

and from this has been deduced the following mixture:—

Oxide of tin ..	100
Chalk ..	34
Oxide of chromium ..	1 to 1½
Chromate of potassa ..	3 to 4
Silica ..	5
Alumina ..	1

The mixture and preparation of the oil for receiving the colors is as follows:—Mix together—

Old linseed oil 2 gallons
Rape oil 1 quart

To which add—

Red lead 2 ounces
Flowers of sulphur 1 ounce

Place the mixture into an iron cauldron suspended over a clear fire until it begins to boil; the scum which rises is then ignited and burnt off, a close-fitting iron disc covered with flannel being used to extinguish the flames. When the scum is consumed, add gradually two ounces more of red lead, and let the scum be burnt off a second time as it rises. As soon as the oil is sufficiently boiled to become adhesive and stringy to the finger, mix with the mass—

Burgundy pitch 2 pounds
Spirits of tar 1 quart
Gum mastic 1 ounce

These ingredients, previously warmed together in a pan, are added very gradually to prevent ebullition, the oil being removed from the fire for that purpose. After the whole has been stirred together for fifteen minutes, it is strained off through a hair sieve and allowed to cool for use. Other oils are sometimes used, but all possess similar powers to the above.

Printed colors are seldom transferred upon the glaze, but are generally printed upon the biscuit, in which case the addition of a flux is not essential, its place being supplied by the glaze.

The process of applying the pattern to the biscuit is as follows:—The design is engraved upon a copper plate in a broad open style, to prevent the lines from running into each other, and forming a blurred appearance. Those portions intended to produce a shaded effect are cut deeper to retain more color. The ink, which is first spread over the surface by a printer's dabber while the plate is on the hot stove, is, after the pattern is well filled in, removed by passing a knife over the surface and wiping with the boss to clean the surface from superfluous oil. The impression is then taken from the plate much after the manner of ordinary copperplate printing, a similar press being employed.

The paper upon which the impression is taken is of a fine, soft, uniform, and durable nature, much about the consistency of tracing paper, and previous to use is saturated with soft soap and well damped. This particular paper is manufactured only in the district under FOURDRINIER's patent. In this manner the various patterns are printed closely upon the paper to economize space, their size being proportionate to that of the ware intended to receive them. After the patterns are separated by scissors, they are placed with the printed side next the ware, and rubbed down upon it with the end of a firmly bound roll of flannel. This is done gently at first, and afterwards more forcibly, until the ink is transferred to the surface of the biscuit. The ware is then plunged into water, when the paper is easily removed after a short time by the gentle application of a sponge. Accurate impressions by this

process can only be obtained when both the surface receiving the transfer and that of the paper bearing the impression are flat. In ordinary manipulations the paper has to be applied to a curved surface with a certain amount of pressure to avoid the creasing, and this, unless carefully performed, is apt to cause a doubling up and distortion of the pattern.

From the circumstance that each differently shaped piece of the same pattern, and each piece of the same shape, but of different size, such as plates, *et cetera*, require a separate engraved copperplate, this becomes a very expensive operation—the process of engraving a set of plates ranging from eighty to one hundred and fifty pounds for the full service, even of the most simple design. This expense is again increased by the unequal wear and tear of the plates, and consequent frequent reproduction of the pattern necessary for a particular piece, such as a plate or saucer, the numbers of which printed, in proportion to other pieces, such as dishes, vegetal covers, *et cetera*, is very large, so much so that often a thousand plates of a pattern are thrown off against one cover or dish.

A very important change in the manipulation as regards the whole process of preparing the designs, regulating the sizes, engraving, and reproducing the plates, has been patented by Mr. WILLIAM MACKENZIE of Glasgow; and the improvements which he proposes are so applicable to the process of decorating clay wares, as regards not only the exactitude and simplicity of the process, but also the economy of production it develops, that ultimately no doubt it will entirely supersede the present expensive system already described. This process may be briefly described as follows:—The intended design is first of all either engraved upon copper or drawn upon stone, of such a size as to fit one of the pieces of the set, say a plate of medium size, and from which an impression in transfer ink is taken, and by a peculiar process transferred to the prepared surface of an elastic sheet. This sheet is afterwards placed on a frame and extended equally in all directions, until the design is accurately brought to the scale required for the plate next in size; while in this extended condition, the pattern is retransferred to the prepared surface of a zinc plate by the ordinary process of lithographic printing. The zinc plate, which has now received the pattern upon the enlarged scale, accurately corresponding in every particular with the original, line for line, is after a little further preparation subjected to the engraving process, *electricity* taking the place of *manual* labor, and in the course of six or eight minutes the plate is finished, presenting all the gradation of depth and tone of the original, only of a different size. The subsequent operation of printing may be greatly simplified, by a chemical preparation of the surface of the zinc, causing a reaction to take place with the oily nature of the ink which then only attacks the engraved parts, and leaves the surface of the plate perfectly free from the ink or grease of the filling-in process. The facility and cheapness with which particular designs can be reproduced, as also the extreme accuracy and uniformity of outline obtainable in repeated patterns, constitute the chief recommendations of this patented process.

After printing, the biscuit cannot immediately be glazed, the oily nature of the mordant or color-vehicle preventing the absorption of the glaze by such portions of the ware as are covered by it. It therefore becomes necessary to destroy this oily consistency by heat before the glaze is applied—a process technically termed *hardening on*. The temperature is raised only sufficiently to burn the oil without producing any chemical action on the color. An oven sometimes employed for this purpose is of the size of a moderate room, quadrangular in shape, and arched above. The room, packed as closely as possible with wares, is luted up, and a small iron box or movable wind furnace, called a *davy*, introduced through a trap in the floor. At the four corners of the chamber, pipes protrude through the roof, and descend nearly to the floor of the room, acting as so many flues to distribute the heat by drawing the flame from the burning cinders to the sides of the chamber. A short pipe is placed in the centre of the roof, the outside aperture of which, furnished with a valve, is connected to those of the four others by levers in such a manner that when the centre one is closed the others are opened, and *vice versa*. After the chamber is fired, this centre valve is kept closed by a rod of lead, the four others being open. The heat from the stove gradually increasing from below upwards, until the temperature of the chamber is raised to the heat at which the leaden rod melts, receives a sudden check by the opening of the centre valve, and the draught being cut off by the closing of the four side valves, the fire is soon extinguished. Other forms of *hardening on* kilns are used for the purpose of destroying the oil; but by such an arrangement as that just described, the most accurate regulation of heat is attained, and at very small expense, the stove consuming the cinders and waste from the baking kilns. The operation of glazing then proceeds in the usual manner.

When the printed pattern is applied to the ware above the glaze, the mordant receives a larger proportion of gum mastic; but where enameling colors are used for the muffle, a *size* is applied to the surface of the glaze, composed of spirits of turpentine, with a small portion of gum mastic dissolved in it; sometimes rosin and sugar of lead being added.

Decoration.—The ornamentation of fine earthenware by the hand and brush is practised only for the production of a certain class of designs, such as flowers, leaves, garlands, dots, *et cetera*, and executed by *artistes* expressly trained for that purpose, and each excelling in a particular branch of ornamentation, such as flowers, foliage, scrolls, and the like.

In the preparation of the several tints used in the higher decorations of porcelain and fine earthenware, great care is required to regulate the exact degree of heat to which the biscuit is raised, with a view to the development of the required tints in the several firings through which the wares pass. The following is the mode of preparation of the various colors and their compounds:—

PREPARATION OF ENGLISH AND FRENCH ENAMEL COLORS FOR PAINTING PORCELAIN AND EARTHENWARE.—*English.*—The beauty and success of the hues in the firing depend in a great measure upon

the purity of the oxides from which they are prepared. They should, therefore, in manipulation always individually represent the same body both in chemical composition and molecular arrangement, so as to be subject to the same changes under similar circumstances. For example, the oxides of iron, chromium, purple of cassius, gold, platinum, *et cetera*, although they may be perfectly pure, are very difficult to work if their precipitation has taken place too rapidly, or at an improper temperature. Under the name of vitrifiable colors are generally classed pigments, without distinguishing between the coloring matter and its base, it being generally supposed that the two substances unite chemically by fusion, and form a homogeneous base; this is only the case, however, in some instances, as, for example, with the oxides of cobalt and the oxides of copper; while in others, on the contrary, as the oxides of chromium, the oxides of iron, *et cetera*, the base is only the vehicle which contains the color, and which serves to fix it upon the surface it is applied to. In considering, therefore, the preparation of the colors properly so called, the *oxides* will be given distinct from the bases or fluxes by which they are fixed upon the surface of the wares.

Oxides.—Amongst the *simple oxides* may be classed—oxide of chromium, oxide of iron, oxide of uranium, oxide of manganese, oxide of zinc, oxide of cobalt, oxide of antimony, oxide of copper, oxide of tin.

Amongst the *oxides mixed with earthy matter*, may be classed chromate of iron, chromate of baryta, chromate of lead, chloride of silver, purple of cassius, umber, sienna, and red and yellow ochres. The mode of preparation of these various materials causes the greatest difference in the quality of the colors into which they severally enter.

Sesquioxide of Chromium—chrome green— Cr_2O_3 —is generally prepared for potters' use by calcining a mixture of equal parts of chromate of potassa and sulphur in a close earthenware crucible at a red heat, the green mass which is produced being well washed to dissolve out the sulphate and sulphide of potassium. The oxide of chromium which remains is further purified by repeated elutriation.

GUIGNET has recently discovered—1869—a new method of preparing oxide of chromium for coloring purposes. A mixture of three parts boracic acid and one part bichromate of potassa is calcined at a temperature of about 932° . An evolution of water and oxygen gas takes place, and there is formed a double borate of sesquioxide of chromium and potassa. This salt, which is stable at the ordinary temperature, is decomposed by water, giving biborate of potassa and sesquioxide of chromium; the latter in the nascent state combines with water, and forms a hydrated sesquioxide of a remarkably fine color. This is separated from the biborate of potassa by decantation and washing, leaving a chrome green of a very solid and brilliant description.

Sesquioxide of Iron— FeO .—This is prepared by the calcination of green vitriol, upon the purity of which the brilliancy of the color in a great measure depends. For the calcination a thick cast-iron vessel or earthenware retort is required. During the operation the

sulphate must be kept continually stirred with an iron rod; the powder at first assumes a yellow hue, passing into brown, and finally a greenish brown, which upon cooling changes to red, a sulphuric acid vapor being eliminated during the process, which continues until the powder is reduced about two-thirds of its volume. It is then taken from the fire and allowed to cool, the red deposit being thoroughly washed from all impurities until the water exudes from the filter perfectly tasteless. A red color of a more brilliant tone is obtained from iron by calcining together a mixture of equal parts of sulphate of iron and sulphate of potassa in a crucible slowly up to a dull-red heat. The pigment is afterwards washed with hot water to remove all impurities.

Alum may also be substituted for the sulphate of potassa, or sienna combined with sulphate of potassa may be substituted for the sulphate of iron; but whichever process is adopted, the preparation of the red oxide requires very careful manipulation.

Oxide of Uranium— U_3O_8 —*Uranoso-uranic oxide*—is prepared from pitchblende, which contains from forty to ninety-five per cent. of oxide, and certain proportions of sulphur, selenium, phosphoric acid, lime, magnesia, alumina, silica, manganese, vanadium, arsenic, bismuth, antimony, zinc, tin, lead, iron, cobalt, nickel, copper, and silver. The powdered pitchblende is dissolved in warm nitrohydrochloric acid, and, after all action has ceased, the excess of acid is expelled by evaporation. The residue being heated with a small quantity of hydrochloric acid and water, the solution is filtered from the sulphur and silica, and also from chloride of lead and silver. The arsenic, lead, and copper, with bismuth and tin, are then precipitated from the filtrate by sulphide of hydrogen, and the solution again filtered and boiled, nitric acid being added to convert the protoxide of iron into sesquioxide, which is precipitated by super-saturating the liquid with a large quantity of carbonate of ammonia; this throws down the iron, together with any lime that may be present, and the greater part of the cobalt and zinc oxides, retaining in solution the uranic oxide, together with portions of the cobalt and zinc. The filtrate is then boiled as long as ammonia continues to be evolved, by which means the three metallic oxides, cobalt, zinc, and uranium are precipitated, with the exception of a small quantity of cobalt, which colors the liquid red. The precipitate is collected upon a filter and afterwards washed, dried, and ignited, till its yellow color changes to a blackish-green; it is lastly digested for several hours with cold dilute hydrochloric acid, which dissolves the two compounds of cobalt and zinc, and leaves the pure uranoso-uranic oxide undissolved.

Manganese—Binoxide of Manganese— MnO_2 .—One of the commonest ores of manganese is found in a state of great purity in Sweden and other parts. The purest variety is that known in commerce under the term of pyrolusite, or black oxide of manganese.

Sesquioxide of Manganese— Mn_2O_3 .—may be obtained by heating pure binoxide of manganese in a crucible to redness until it ceases to evolve oxygen; or by exposing protonitrate of manganese to a red heat, the sesquioxide remains as a black powder.

Protoxide of Manganese— MnO .—may be economically prepared by heating chloride of manganese to redness with twice its weight of carbonate of soda and a little chloride of ammonium, exhausting the fused mass with water when cold; the residuum is protoxide of manganese.

Oxide of Zinc— ZnO .—is obtained by distilling zinc from clay retorts into chambers through which a current of air is maintained, the volatilized metal burns at the high temperature to which it is exposed, and the oxide is deposited in a series of condensing chambers. The hydrated oxide may be obtained by precipitation from the solutions of the salts of zinc by the addition of an alkali. An excess of the alkaline liquid redissolves the oxide.

Oxide of Cobalt, the ores of which, after grinding and roasting, to drive off as much as possible the excess of arsenic and sulphur, are dissolved in hydrochloric acid, sometimes with the addition of a small quantity of nitric acid. The copper, lead, silver, arsenic, antimony, &c. are precipitated by sulphide of hydrogen, and to the filtered solution carbonate of lime is added in the form of chalk, by which all the iron, alumina, and a trace of cobalt are thrown down, the nickel and cobalt remaining in solution. To this solution, which must be hot and neutral, a solution of bleaching powder is added in sufficient quantity to precipitate the cobalt, and the menstruum is then well boiled to remove the chlorine as fast as possible. The oxide of nickel is afterwards precipitated from the filtrate by the addition of hydrate of lime, and ebullition.

Oxide of Antimony— Sb_2O_3 .—This is found native as white antimony ore, and may be prepared artificially by boiling pulverized antimony with moderately strong nitric acid, until it is converted into a white powder, which is freed from the excess of acid by repeated washings in boiling water. One part of powdered antimony digested with two parts of aqua-regia and four parts of water, yield 96.6 parts of antimonious oxide. A mixture of seventy-four parts antimony, thirty-nine of nitrate of potassa, and thirty-four of bisulphate of potassa is projected into a red-hot crucible, the ingredients being added rapidly one after another. The resulting mass, after boiling first with pure water, then with water containing a small quantity of sulphuric acid, and afterwards with pure water, will be the antimonious oxide.

Oxides of Copper—red oxide of copper— Cu_2O .—is prepared by heating one hundred parts of blue vitriol with fifty-seven parts of carbonate of soda until the water of crystallization is expelled. The residuum is afterwards mixed with twenty-five parts of copper filings, and the mixture finely stamped into a crucible. It is then exposed to a white heat for about twenty minutes, and after cooling and pulverization, the mass is well washed with water. This process yields about fifty parts of fine colored red oxide of copper.

Black Oxide of Copper— CuO .—The red oxide passes into the protoxide of copper when heated in the air; or it may be conveniently prepared by exposing a mixture of one part of copper filings and two parts of the deliquesced nitrate of copper to the air until the whole is converted into a basic salt, and then igniting

the salt. It communicates a green, and sometimes a blue tint to vitreous compounds; and DAVY has shown that it is the basis of certain colors used by the ancients, which had been supposed to contain cobalt.

Oxide of Tin— SnO_2 —may be prepared by treating the metal with nitric acid. In its most concentrated form the acid does not immediately act, but will violently effervesce with heat upon the addition of a few drops of water. The peroxide of tin remains in the form of a white insoluble powder, and is purified by washing with boiling distilled water, and drying at a dull-red heat.

Chrome Iron Ore— $\text{FeO Cr}_2 \text{O}_3$ —The native chromate of iron is a compound of oxide of chromium with protoxide of iron, but part of the ferrous oxide is replaced by magnesia, and part of the chromic oxide by alumina. By analysis the constituents are as follow:—

Magnesia	7.49
Iron	20.99
Oxide of chromium	59.96
Alumina	11.56
	100.00

Chromate of Baryta— BaO CrO_3 —is prepared by dropping a solution of chromate of potassa into a solution of chloride of barium; the yellow precipitate must be well washed, and is as insoluble in water as the sulphate of baryta.

Dichromate of Lead— $2 \text{PbO}, \text{CrO}_3$ —*chrome red*—may be obtained by boiling oxide of lead, or its carbonate, with an aqueous solution of monochromate of potassa, or by digesting the neutral chromate of lead in a dilute solution of caustic potassa. LIEBIG prepared it by adding a neutral chromate to fused nitre, and washing the residuum; it is an insoluble, scarlet colored powder.

Chromate of Lead— PbO, CrO_3 —*chrome yellow*.—When chromate of potassa is added to a soluble salt of lead, both solutions being hot, a fine colored anhydrous precipitate is obtained; if the solutions are cold, the precipitate will be pale yellow, and will contain an equivalent of water.

Chloride of Silver— Ag Cl —is best obtained by adding a solution of chloride of sodium in excess to a slightly acidulated solution of nitrate of silver. The curdy precipitate of chloride of silver requires very careful washing.

FLUXES.—General Flux.

Red lead	3	} Fritted together into a perfect glass, and pounded for use.
Borax	2	
Flint	1	

Soft Lead Flux.

Red lead	3	} Ditto.
Flint	1	

White Flux.

Glass	12	} Ditto.
Borax	14	
Flint	9	
Red lead	6	

Chrome Flux.

Red lead	4	} Ditto.
Flint glass	1½	
Flint	1	

Purple Flux.

Glass	16	} Fritted together into a perfect glass, and pounded for use.
Borax	10	
Lead	9	
Flint	4	

Soft Borax Flux.

Borax	4	} Ditto.
Flint glass	3	
Cornish stone	½	

COLORS.—White Opaque Enamel.

Flint glass	16	} Run into mass in flinted crucibles or saggars in glazing oven.
Arsenic	1½	
Nitre	1	
Red lead	4½	

White Opaque Enamel.

Oxide of tin	1	} Calcined in biscuit oven, and 1½ of calcine added to 2 parts of general flux, and afterwards run down again in glazing oven.
Felspar	1½	

Yellow.

Under glaze yellow	1
General flux	2½

Orange.

Under glaze orange	1
General flux	2½

Red.

Green vitriol calcined to drive off the water of crystallization, and brought to a pale red tint, and then well washed until perfectly free from the sulphuric acid. Here great care is required to obtain the proper tint, neither too pale nor too dark.

Of this calcine take	1½
General flux	2½

Chocolate.

Same preparation of vitriol at the heat of a glazing oven, well washed as the foregoing, and fluxed.

Calcine	1
General flux	3

Dark Brown.

Umber	1	} Calcine together in glazing oven, well washed, and to 1 part of calcine add 2 parts of general flux.
Sienna	½	
Red oxide of iron	1	
Oxide of zinc	1½	

Another Dark Brown.

Umber	1 part.	} Calcined in glazing kiln.
Calcined terra sienna	1½ parts.	
Oxide of iron	1 part.	
Oxide of zinc	1½ parts.	

To one part of the calx add three parts of general flux. Ground for use.

French Yellow Brown.

Oxide of tin	2½ lbs.	} Calcine in kiln, and to 1 part of calcine add 2½ parts of general flux.
Oxide of zinc	2 lbs.	
Red oxide of iron	1½ lbs.	

Another Yellow Brown.

Oxide of tin	3 parts.	} In glazing kiln.
Oxide of zinc	2 parts.	
Oxide of iron	2½ parts.	

To one part of the above add three parts of general flux.

Base for Copper Green.

Flint glass	12	} Run down in glazing oven.
Red lead	27	
Borax	9	
Flint	6	
Oxide of copper	2	

Black.

Calcined umber	1	} Calcine in kiln, and to every 4 parts add 3 parts of general flux.
Blue cobalt calx	1	
Flint glass	1	
Red lead	1	
Borax	1	
Flint	1	

Another Black.

Black oxide of cobalt	2 1/2
Turkey umber	1 1/2
Soft borax flux	2 1/2

Another Black.

Black oxide of copper	1 part.	} Calcined in glazing oven.
Oxide of cobalt	1 part.	
Oxide of manganese	1 part.	
White flux	10 parts.	

To four parts of the above add one and a half parts of white flux.

White Enamel.

Flint glass	20	} Run down in glazing kiln.
Red lead	5	
Nitre	1 1/2	
Arsenic	1 1/2	

Sometimes an addition of the oxide of tin.

Blue Green.

Base as above	10 parts.
White enamel	1 1/2 parts.

Yellow Green.

Base	10 parts.	} Run down.
Enamel yellow	15 parts.	
White enamel	1 1/2 parts.	

Chocolate Brown.

Crocus mentis	4 parts.	} Run at gentle heat.
General flux	12 parts.	

Deep Blue.

Flint glass	4 parts.	} Run in glazing kiln.
Red lead	1 1/2 parts.	
Pearl ash	1-16th part.	
Muriate of soda	1-16th part.	
Carbonate of cobalt	1/2 part.	
White enamel	1/2 part.	

Mat Blue.

Carbonate of cobalt	2 parts.	} Run in glazing kiln.
Oxide of zinc	2 parts.	
Borax flux	4 parts.	

To two parts of the above add one part of borax flux. Run down at a gentle heat.

Rich Chrome Red.

Red lead	3 parts.	} Run down at a gentle heat.
Chromate of lead	1 part.	
Chrome flux	2 parts.	

Green from Oxide of Chrome.

Oxide of chrome green	3 parts.	} Calcined at high heat, and well washed.
Carbonate of cobalt	1 part.	
Felspar	2 parts.	

To one part of the above add four parts of soft borax flux. Run down.

Various tints of green obtained by the addition of enamel yellow, previously given.

FRENCH ENAMEL COLORS.

FLUXES.

No. 1.—Bocaille Flux.

Red lead	75	} Run down at low heat.
Sand	25	

No. 2.—Grey Flux.

Red lead	66	} Run down as above.
Sand	22	
Calcined borax	12	

No. 2 S.

Red lead	60	} Run down at low heat.
Sand	15	
Boracic acid	25	

No. 3.—Carmine Flux.

Red lead	12	} Run down as above.
Sand	33	
Calcined borax	55	

No. 4.—Purple Flux.

Red lead	36	} Run down as above.
Sand	14	
Boracic acid	50	

No. 5.—Violet Flux.

Red lead	68	} Run down as above.
Sand	5	
Boracic acid	27	

No. 6.—Green Flux.

Red lead	73	} Run down as above.
Sand	9	
Boracic acid	18	

FRENCH COLORS.

Dark Grey.

Carbonate of cobalt	6	} Run down at low heat.
Oxide of zinc	13	
Yellow oxide of iron	13	
Flux, No. 2 or No. 2 S	68	

Russet Grey.

Carbonate of cobalt	6	} Run down to the tint required.
Oxide of iron	3	
Oxide of zinc	3	
Flux, No. 2	88	

Black Grey.

Carbonate of cobalt	10	} Run down.
Oxide of cobalt	5	
Flux, No. 2	85	

Brown Black.

Carbonate of cobalt	16	} Ditto.
Oxide of iron	8	
Flux for greys, No. 2	68	
No. 2 S	76	

Iridium Black.

Sesquioxide of iridium	25
Flux for greys, No. 2	75

Dark Indigo Blue.

Carbonate of cobalt	14	} Calcined in kiln.
Carbonate of zinc	26	
Flux for greys, No. 2	60	

Sky Blue.

Carbonate of cobalt	7	} Ditto.
Carbonate of zinc	14	
Flux, No. 2	79	

Blue Green.

Oxide of chrome	50	} Calcined at a high heat.
Carbonate of cobalt	25	
Carbonate of zinc	25	

To twenty-five parts of the above add seventy-five parts of flux, No. 3 or No. 6. Ground for use.

Clear Yellow.

Antimoniate of potassa	12	} Run at gentle heat.
Carbonate of zinc	6	
Oxide of iron	2	
Flux, No. 2 or No. 2 S	80	

Jongquil Yellow.

Lead and tin ashes	8	} Mix and run down.
Calcined carbonate of soda	3	
Antimoniate of potassa	3	
Flux, No. 1	86	

Chrome Orange.

Chromate of lead 25 } Run down together.
Red lead..... 75 }

Uranium Orange.

Oxide of uranium 25 } Run down.
Bocallie flux, No. 1 75 }

Red.

Red oxide of iron, prepared from sulphate of iron by gentle calcination to the required tint.

To twenty-five parts of the above add seventy-five parts of flux, No. 2 or No. 2 S.

Sepia Brown.

Red oxide of iron 12 } Run down.
Oxide of zinc 12 }
Carbonate of cobalt 3 }
Flux, No. 2 or No. 2 S .. 70 }

Russet Brown.

Oxide of iron 12 } Run down.
Oxide of zinc 12 }
Sepia brown 3 }
Flux, No. 2 72 }

Various tints of green are produced from the oxide of chrome, with the addition of yellow as given.

Carmine, purple, and rose colors are from the purple of cassius, prepared by precipitating gold from the solution of aqua-regia by nitromuriate of tin; to which precipitate is added a small proportion of chloride of silver, and the flux—No. 3 for carmine, or No. 4 for purple—in proportion, according to the heat required in the process of firing, to produce a fine tint.

Purple of Cassius.

The acids used for the solution of gold for this process are, hydrochloric 1·13, and nitrous 1·41—three parts of the former to one part of the latter. Ten pennyweights of the above aqua regia will dissolve one pennyweight of fine yellow gold. For the solution of tin, twenty pennyweights of hydrochloric acid, ten pennyweights of nitrous acid, and twenty pennyweights of pure water, dissolve in these quantities ten pennyweights of well granulated tin. The tin must be added by small pieces, each being allowed time to dissolve before more is added, and so on to saturation, when the solution, if properly performed, should assume the clear and bright color of brandy. Great care is required for the performance of these processes.

Many other forms are given by various authors, each preferring their particular methods. The solutions here described having been prepared, the processes will be now given.

Into a vessel of sufficient dimensions pour two quarts of good pure water, into which the solution of gold is to be poured, when it will, in its diluted form, assume a pale straw color; into this the solution of tin is to be carefully added, and stirred continuously with a glass spatula until the cassius is well formed, and the precipitate should be of a brilliant carmine tint. Time having been allowed for the cassius to subside, the water is to be carefully removed by a syphon, and washing continued, by changes of the water, until the cassius is perfectly free from the acids. The cassius must then be carefully collected on a filter, and, whilst in a moist state, is ready for further use.

Rose Color.

The cassius, with fifteen grains of silver and sixteen ounces of flux.

Flux.

Flint glass 4 parts.
Borax 2 parts.
Red lead 2 parts.
Flint 1 part.

VOL. II.

To form the Cassius for Purple Color.

Gold solution 10 pennyweights.
Tin solution 20 pennyweights.

The Cassius with

Silver..... 10 grains.
Flux 6 ounces.

Purple flux is already given.

Fine earthenware, although chiefly confined to the potteries in Staffordshire, is also made in considerable quantities abroad—in France, in the neighborhood of Paris, at Bordeaux, Saargemünd, *et cetera*; in Germany, at Mettlach, near Saarbrück, and Poppelsdorf, near Bonn. Earthenware is also made at Baireuth, Aschaffenburg, Kolsterbach, *et cetera*, and at Carlsbad in Bohemia; at all of which places several kinds are produced simultaneously with the fine earthenware. The differences in the manufacture are confined chiefly to the manner of preparation of the clay, the composition of the glaze, and the ornamental decoration. At Mettlach four varieties are manufactured.

1. *Stoneware*, composed of plastic clay from the Palatinate, ground quartz from Oberwald or Berncastle, calcareous tufa from Sierk. The glaze contains lead, and the ware has a yellow tint.

2. *Yellow or Nankin-colored earthenware*, composed of grey plastic clay from Vallendar, near Coblenz, and clay from Eifel, which burns yellow. The glaze contains lead.

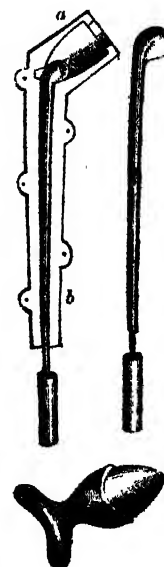
3. *Hard Stoneware*, containing plastic clay from the Palatinate, and ground quartz and gypsum from Luxemburg. The glaze a tolerably hard lead glass, containing boracic acid.

4. *Porcelain Stoneware*, containing plastic clay from the Palatinate and from Vallendar, with ground quartz and bone ashes. The glaze free from lead, and composed of borax, alkali, and felspar.

Amongst the varieties of fine earthenware may be classed the peculiar manufacture of *clay pipes*. The clay used in the construction of these requires extreme plasticity, together with a certain amount of porosity upon firing. The plastic clay found in the layers forming the basis of the clay deposit, is used without the addition of a flux, but to insure the perfect uniformity and pliability of the mass, great care is taken with the kneading and slapping processes.

The manufacture of tobacco pipes, in consequence of the immense demand for them, is one of considerable importance in the potter's art. From a prepared lump of the clay the moulder separates a number of pieces, each sufficient for the construction of a pipe, and rolls them out on a table two at a time, one in each hand, to nearly the form and dimen-

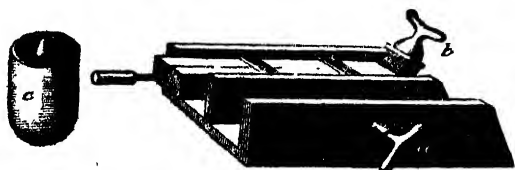
Fig. 484rk.



sions of the intended pipe, the thinner portion having rather more than the thickness of the future tube, whilst the bulbous portion at the end is somewhat less in diameter than the bowl. When these rolls have become sufficiently hardened by exposure to the air, a second workman receives them in bundles for the operation of boring the tube by means of an oiled wire mounted in a wooden handle. With his left hand he forces forward the oiled wire, whilst the thumb and forefinger support the roll, and with a kind of feeling motion guides the point of the wire very accurately along the axis of the roll. The point of the wire is rounded like a button to facilitate the operation, which is performed with surprising celerity.

The whole length of the pipe is not pierced at once, an inch being left unbored, and the unfinished pipe with the wire is placed in the half of the copper mould, *a*, *b*—Fig. 484KK—previously brushed with oil to give smoothness to the stem upon removal. The two halves of the mould, closed accurately together by means of pins, are then placed in a frame—Fig. 484LL—and the edges kept in contact by the screw vice, *a*.

Fig. 484LL.

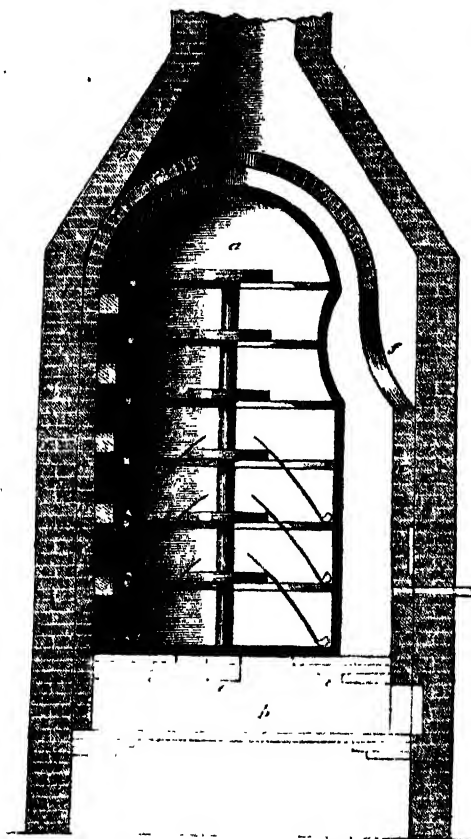


The stem is thus shaped in the mould, together with any impress or name that may have been cut upon it. The bowl of the pipe is first roughly formed by the introduction of the finger, and afterwards completed by the insertion of the plug, *b*, into the mould. Upon opening the mould the operation of boring is completed, the small pollet of clay which precedes the wire being removed by a little hook attached to the handle of the knife used for forming the edges and bowl of the pipe, which is done by removing the superfluous clay. Finally, the rim of the bowl is formed by the small copper mould, *c*. When the pipes have been removed from the moulds, and the wires drawn out, any ornamentations not given by the pipe mould are added by means of roulettes and stamps. The pipes are then laid out to dry, the sutures removed with a sharp knife, and polished by grooved agates. When the stem of the pipe is required to be curved instead of straight, the two extremities only are supported upon the drying boards, causing the centre to sink down. The number of complete pipes produced by a good moulder will average five hundred a day, notwithstanding the number of operations each pipe has to undergo.

The white color of the pipe being an essential requisite, requires that they be fired in seggars. When the pipes are short, and there is little risk of fracture or bending, as many as possible are placed in the seggar without reference to any particular arrangement;

but for firing long pipes, ring-formed projections upon which the bowls of the pipes rest, are made on the inside of the seggars, a grooved column in the centre supporting the ends of the stems, which, when projecting above the seggar are protected by a conical lid. In London the clay-pipes noted for elegance of form are fired in a close kiln—Fig. 484MM—shown in section, and from which the flame and smoke of the fire are totally excluded. The bottom and sides of

Fig. 484MM.



the kiln are constructed of similar material with the pipes themselves, the refuse and fragments of old pipes being worked up for this purpose. This close kiln, *a*, is supported over the fire-place, *b*, by the brackets, *e*, a space of several inches being left between the sides of the kiln and the outer casing of the fire-brick, *c*, and the whole inclosed by the *hovel* of brickwork, *d*. The flame circulates freely in the intermediate space between the kiln and casing, *c*, supports being introduced at intervals to keep the kiln in its proper position, and which, being connected together by occasional apertures, serve at the same time the purposes of flues to regulate the direction of the flame. The opening, *f*, in the lining of the kiln, *c*, for the introduction and removal of the pipes, is closed during firing by an iron door luted with clay. The corresponding opening in the kiln itself is plastered

up after charging with clay and broken fragments of pipes. The pipes are supported in the kiln by rings of clay, *g g*, surrounding the sides and the central bearings, *m m*, the weight of the whole charge being distributed between the sides of the kiln and the central column, so as not to bear upon the lowest layer of pipes. These kilns vary in size, and sometimes fire a hundred gross of pipes at once. The firing lasts from ten to fourteen hours, the temperature being gradually raised to the full intensity required for baking. The fuel used is coke, and a small opening, *r*, is left in front of the kiln to enable the workman to judge of the interior temperature.

The porosity of the biscuit causes the burnt pipes to absorb water with avidity, and to adhere in a very unpleasant manner to the lips. The ends of the stems are therefore either rubbed with a mixture composed of gum, soap, and wax, or coated with resin or shellac. Sometimes they are glazed by dipping into a very fusible lead glaze; the covered ends being afterwards exposed to the flame of the furnace for about ten minutes.

Description of earthenware.	Silica.	Alumina.	Lime.	Magnesia.	Oxide of iron.	Carbonic acid and loss.	Remarks.
Italian, from Lucca della Robbia,	49.65	15.50	22.40	0.17	3.70	8.58	All effervesce with acids.
Majolica,	48.00	17.50	20.12	1.17	3.75	9.46	
Old Spanish,	46.04	18.45	17.64	0.87	3.04	13.96	
Manassas, near Valencia,	54.71	18.80	19.69	trace	2.20	4.60	
Delft,	49.07	16.19	18.01	0.82	2.82	13.09	
Persian,	48.54	12.05	19.25	0.30	3.14	16.72	
From Rouen,	47.96	15.02	20.24	0.44	4.07	12.27	
From Nevers,	56.49	19.22	14.96	0.71	2.12	6.50	
From Paris,	61.50	12.99	16.24	0.15	3.01	6.10	

The mean of these proportions corresponds nearly with equal parts of silica, pipe-clay, and carbonate of lime. These analyses likewise show that the greater portion of the carbonate of lime has been decomposed by the silica during firing, the amount of carbonic acid contained in the vessels being far too small a quantity to combine with the whole of the lime. All kinds of delftware melt and swell at a high temperature into the form of a dark-brown or green glass, without becoming translucent. The liability to crack, when exposed to sudden variations of temperature, is likewise increased by the large amount of marl in the mass. A corresponding increase of pure clay diminishes the risk.

All the ingredients for delftware are suspended in water, and mixed in the slip state; the mass being brought to the proper degree of consistency for working by evaporation in slip kilns. The operation of forming or moulding upon the throwing-wheel is one of extreme rapidity from the great plasticity of the mass; the finishing processes being afterwards performed upon the lathe. Sometimes plaster moulds are employed; but, in every case, the processes are the same as those already described.

Firing.—Delft earthenware, like fine earthenware, is fired twice; the first baking producing the *biscuit*, which, after receiving the glaze, is fired the second time. Both these operations are carried on in similar kinds of kilns, which are generally upright reverberatory furnaces heated by one or more fire-places, after the manner of those already described. In the firing, the wares of better quality are protected from the flame by inclosure in seggars, while the commoner kinds receive

Common Earthenware or *Delftware* is characterized by its extreme opacity, its open porous structure, and soft texture; in fracture it is earthy, and always colored, while, instead of a transparent glaze, it is coated with enamel.

In the composition of the mass, certain proportions of potter's and plastic clay, clay marl, and quartz or sand, will always be found—these constituents varying in their nature according to the different localities in which they occur. Thus Paris earthenware consists of—

Plastic clay from Arcueil,	8
Greenish clay marl,	36
White calcareous marl,	28
Yellowish marly sand,	28
	100

Still the various combinations always contain a mean proportion of clay, silica, and carbonate of lime, as will be seen by the following analyses of earthenwares from various localities:—

support in the kiln by clay slabs specially prepared for this purpose, and arranged in separate layers or floors, between which the wares are placed so as to afford free circulation to the flame. The pieces are separated from each other in the seggars by triangles and pegs, as already described. The first firing lasts from fifteen to sixteen hours, and the second for burning on the glaze from twelve to fourteen hours.

The temperature of the kiln averages about 27° Wedgwood. The mass shrinks in the baking from ten to twelve, fourteen, or even fifteen per cent. according to its composition.

The analysis of common delft earthenware is as follows:—

Alumina and sesquioxide of iron,	68.55
Silica,	29.13
Lime,	1.24
	98.82
Specific gravity,	2.363

The glaze or enamel is composed of quartz-sand, soda, common salt, and a mixture of calcined tin and lead. The two metals are more easily oxidized when mixed; the oxide of tin produced— SnO_2 —acting the part of an acid to the oxide of lead— PbO . The mixture is prepared by placing the lead with about one-fourth of tin in a special furnace, where it is exposed to heat and a current of air. A yellowish ash of tin and lead is formed, which is carefully calcined to oxidize thoroughly all the metallic particles. This metallic ash is mixed to form the enamel in the following proportions:—

No. 1.	
Lead and tin ash,	100 parts.
Sand,	100 parts.
Salt,	15 parts.
Red lead,	5 parts.

{ All sand for opaque glazes should be fritted with soda as follows:—150 sand to 100 soda.

No. 2.	
Lead and tin ash,	32 parts.
Soda,	9 parts.
Salt,	5 parts.
Cornish stone,	25 parts.

{ Fritted together, with the addition afterwards of 50 pounds of white lead.

No. 3.	
Calcined sand,	100 lbs.
Soda,	50 lbs.
Tin ashes,	25 lbs.

{ Fritted together, with the addition afterwards of 100 pounds of white lead.

No. 4.	
Best earthenware glaze,	10 quarts.
Oxide of tin,	40 oz.
White lead,	60 oz.

The larger the proportions of tin in the ash the harder the enamel produced, and *vice versa*. The frit, ground and mixed with water, is applied to the wares in the usual way.

Majolica ware—the revival of which in this country is due to MESSRS. MINTON, under the direction of M. ARNOUX. The body consists of a soft calcareous clay, or common delftware body, gently fired and covered with an opaque enamel composed of sand, lead, and tin, forming an excellent surface, upon which the decorations in color are afterwards painted by hand in the various preparations and fired into the glaze. Very elegant cisterns, vases, flower stands, *et cetera*, are now produced in this ware; it is also applicable for the production of friezes and other architectural ornaments. It likewise affords a cheap material for enamel painting, the brightness of tints attained being equal to that produced upon copper. The mode of production may be thus described:—The ware, after formation in the usual manner, is twice fired, first for the biscuit, and afterwards to receive the enamel or basis for receiving the color. In this state it is taken to the decorator, who with his brush paints on the several pigments prepared for the purpose, the ground color being only laid upon such portions as are to be covered, and the several ornamentations added in the same way, each only receiving its particular tint. Great care and nicety are required in this manipulation to prevent the unequal blending of the colors at the edges. Sometimes a shaded effect is given to the ground or ornamentation by the running of the colors into the hollows of the pattern, causing in the firing a greater depth of tone. At other times color is laid over the first ground, and a pleasing blended effect is produced by the running together of the enamels in firing. After the decoration is completed in this manner, the piece is taken to the *muffle*, where the colors are all burnt or fired into the glaze, giving that rich solidity of tone and lustre so peculiar to *majolica* ware. The proportions for the enamel are here given:—

ENAMEL GLAZING FOR MAJOLICA WARE.

No. 1.	
Lead,	77
Tin,	23
Calcine together, and take—	
12	

Calcine,	44 parts.
Sand,	44 parts.
Red lead,	2 parts.
Salt,	8 parts.
Soda,	8 parts.

No. 2.	
Lead,	83
Tin,	18
Calcine, and take—	
Calcine,	47 parts.
Sand,	47 parts.
Salt,	8 parts.
Soda,	3 parts.

No. 3.	
Lead,	77
Tin,	23
Calcine together, and take—	
Calcine,	45 parts.
Sand,	45 parts.
Red lead,	2 parts.
Salt,	5 parts.
Soda,	3 parts.

No. 4.	
Lead,	82
Tin,	18
Calcine together, and take—	
Calcine,	45 parts.
Sand,	45 parts.
Salt,	7 parts.
Soda,	3 parts.

All these compounds are fused together, and sometimes yield a blackish mass; but when ground and applied to the wares, they appear as a white enamel glazing.

The following are the colors applied to them:—

Yellow.	
White enamel glazing,	91 parts.
Oxide of antimony,	9 parts.

Blue.	
White enamel glazing,	95 parts.
Cobalt calx,	5 parts.

Green.	
White enamel glazing,	95 parts.
Oxide of copper,	5 parts.

Yellow Green.	
White enamel glazing,	94 parts.
Oxide of copper,	4 parts.
Naples yellow,	2 parts.

Violet.	
White enamel glazing,	96 parts.
Peroxide of manganese,	4 parts.

Other colors are merely modifications of these, with other compounds.

The white glazing of some of the modern *majolica* is composed of felspar, borax, and the oxide of tin. This glazing, as well as the colors, is frequently applied directly to the biscuit ware, which considerably reduces the labor of ornamentation, without detracting from the beauty of the manufacture.

ORDINARY POTTERY, such as is now everywhere produced, is intended to afford the less wealthy classes cheap utensils, that are *impervious to liquids*, and which at the same time will *bear changes of temperature*, so as to admit of general domestic use. Ordinary pottery is made in almost every locality, and therefore, of necessity, from very different kinds of clay. Its

extreme cheapness obliges the use of those clays that can be obtained at least expense, such as potter's clay, marl, *et cetera*, and the application of the most ordinary methods of moulding and firing. From the circumstance that ordinary pottery is generally manufactured by a class of persons without the means and opportunities of introducing improvements, the advance of the manufacture is slow; the waste of fuel in badly constructed kilns is frequently a source of great loss, while many of the clays worked into the mass will not withstand a sufficiently high temperature. Ordinary pottery is, therefore, always fired at a comparatively low heat, which renders the mass porous and of low density, and necessitates the use of a glaze. As the temperature required to burn on this glaze must be lower than that which would cause the fusion of the ware, it is generally a lead glaze, and of a very fusible nature. This glaze is always transparent, no attempt being made to conceal the body of the ware, which is generally of a dirty-red, yellowish-brown, or greyish color. The glaze may either be colored or not, the rude paintings with which ordinary potters' ware is sometimes decorated being produced by glazes of different colors, the one forming the ground and the other the ornamentation. In general, a very low style of art pervades the tone of this class of clay wares, though occasionally exceptions are met with, such as the wares produced at Marburg, where the brown colored vessels are neatly ornamented with floral designs, that appear to advantage through the light yellow glaze.

In the preparation of the mass two operations only are required—one, the mixing the clay with the necessary amount of water to bring it to the proper consistency, and during which operation the clay is frequently stirred and turned over to render the action of the water uniform; the other, after evaporation, is the working the mass into lumps, and the removal of all knots, stones, *et cetera*, by the aid of the wire, as already described under *Earthenware*. Clay, when of good quality, is easily worked upon the throwing wheel, and does not shrink so much in the kiln as to cause cracks, besides possessing the qualification of carrying the glaze. These properties, which cannot be previously determined, are all matters of experience, different clays being frequently mixed together for that object, with the addition of sand to diminish contraction when the clay is too fat.

The glaze in use upon ordinary potters' ware is an aluminous lead glass prepared from litharge or galena, which in the firing forms oxide of lead and lead salts, the former combining with the silica.

The substances containing the lead are finely ground and mixed in proper proportions with loam, or if a transparent colorless glaze, with sand. When color is required, metallic oxides are used as pigments—oxide of copper for *green*; manganese for *brown* and *black*; zaffre for *blue*; red antimony ore for *yellow*; and iron for *red*, *et cetera*.

The glaze is generally applied to the surface of the ware either by coating or sprinkling the moist vessels with the glaze powder, the operation of dipping being in general too expensive for this kind of ware.

The proportions between the oxide of lead and silica in the glaze are very variable, sufficient time being generally allowed in the furnace for the oxide of lead to become fully saturated with silica. That this is the case when the heat of the furnace has been sufficiently intense, is demonstrated by the following results of experiments made on twelve vessels specially marked, and after firing digested for some time in distilled vinegar—

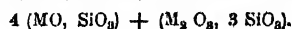
Those too hard fired gave no indications of lead.
Those hard fired gave no indications of lead.
Those well fired gave in some cases only traces of lead.
Those ill fired gave in every case indications of lead.

In badly baked ware, therefore, acid liquids upon the first application dissolve the oxide of lead which is uncombined, or only in weak combination. The amount of lead so dissolved, however, is very small, and the application of lead glaze to the wares is not attended with any danger to the consumer, notwithstanding the great outcry that was raised against its use as engendering endemical diseases.

Often glazes free from lead are used, especially in Vienna, where the glaze contains—borax, one hundred pounds; felspar, fifty pounds; loam, fifty pounds. In Bavaria the glaze consists of the slag from the smelting furnaces, a transparent mass harder than glass, and which gives sparks when struck with steel; in color it is either bottle-green or light and dark blue passing into green; it is not acted upon by acids. In the analyses made by REINSCH it was found to consist of—

		Oxygen.	
Silica,	65.00	.....	33.70 in the silica.
Lime,	12.35	.....	3.53
Magnesia, ..	2.56	.....	0.99
Potassa,	2.00	.....	0.34
Protoxide of iron,	5.00	.....	1.50
Alumina,	8.00	.....	3.73
Oxide of manganese, ...	4.45	.....	1.33
	99.36		
			7.37 in the bases
			MO.
			5.06 in the bases
			M ₂ O ₃ .

Corresponding very closely with the formula—



Although not identical with bottle glass, it is nearly allied to it. This slag is ground up with water, and applied by pouring it over the ware, previously coated on the outside by immersion with a thin film of loam, to give the red-brown tint. The high temperature required for the fusing of this slag, is one of the chief objections attending its use and general introduction as a glaze.

The kilns in which ordinary potters' wares are fired are long, horizontal, reverberatory furnaces with one fire-place, from which the flames traverse the introduction of the ware, the smaller pieces in lengthwise towards the chimney situated at the opposite end, and in which is the aperture for charging the kiln being placed inside those of larger dimensions. As the temperature of the kiln diminishes rapidly towards the chimney, a proper disposition of the wares is necessary, those coated with the more fusible lead glaze being placed where the temperature is lowest. The wares are all exposed to the direct action of the flames, precaution being taken to prevent their adhesion together

in the fusion of the glaze. Further description or illustration of the ordinary potter's kiln is here unnecessary, the wares being frequently fired in the same kilns with stoneware and bricks, an account of which will be found under the article *Tiles*.

The application of glaze to common potters' ware is sometimes omitted, as in the case of articles for which rapid absorption or evaporation is necessary, such as water coolers, sugar-moulds, butter-dishes, flower-pots, *et cetera*.

The cooling bottles and vessels used for holding liquids illustrate well the use that is made of the porous nature of unglazed clay. Their cooling properties arise from the permeation of the liquid through the pores of the ware to the exterior surface where, by exposure to the air, it is evaporated with great rapidity, maintaining the interior liquid at a temperature several degrees below that of the surrounding atmosphere. The porosity is sometimes increased by the admixture into the mass of substances which will be destroyed in the kiln, leaving minute pores through the body of the ware; a similar effect is produced by a low temperature of the kiln during firing.

Lustre ware is a class of common pottery which receives upon the glaze, after firing, a very thin, delicate, and brilliant coating of metal, burnt in by a subsequent process in a muffle. The reduction of the metal is effected either by some ingredient in the solution, or by a reducing atmosphere through the action of heat. Sometimes the lustre imparts color to the glaze, as well as the metallic coating, an effect of the extreme tenuity of the coating and partial oxidation of the metal.

This effect is produced in a remarkable manner by the *gold lustre*, which is obtained by precipitating a solution of gold in aqua-regia by means of ammonia, the precipitate, which is fulminating gold, being mixed while moist with essential oil of turpentine. In this state it is applied to the surface of the ware, and fired in the muffle, the lustre being brought out afterwards by friction with linen.

Another preparation for the gold lustre is as follows:—Two pennyweights of gold, dissolved in twenty-five drachms of aqua-regia, with about sixty drops of the solution of tin; the solution being gradually added to six ounces of balsam of sulphur, into which a pint of spirits of turpentine is slowly added, constantly stirring until the whole mass is smooth.

Platinum Steel Lustre is formed from a solution of bichloride of platinum in ammonia, mixed by means of a glass rod with *spirit of tar*, composed of equal parts tar and sulphur, boiled in linseed oil, and filtered. The mixture is spread upon the piece, and fired in the muffle, great attention being paid to the temperature of the kiln. If the platinum solution is too strong, it is reduced by the addition of more spirits of tar, and if too weak, concentrated by evaporation. If the wares come out black from the kiln, friction with cotton restores the proper color.

Silver Lustre, which has a silver white hue, is also obtained from platinum, dissolved in equal parts of muriatic and nitric acid; the saturated solution is poured into boiling water, and a yellow precipitate of

the metal is obtained by pouring this mixture into a warm solution of sal ammoniac, which, after being well washed with water and dried, is applied in the usual way to the surface of the ware by means of a flat camel-hair pencil; it is then fired, not beyond a red heat, and afterwards burnished with a piece of soft leather.

Lustre Cantharide—the remarkable iridescence of which resembles beetles' wings or Spanish flies—is produced from glass containing a large quantity of lead, and to which is added oxide of bismuth and chloride of silver. The wares after coating with the preparation are placed in the muffle, and when heated to redness, leather or similar substances thrown in, the products from which reduce the surface of the metal and produce brilliant coatings, varying in color from green, red, yellow, blue, *et cetera*.

Iron Lustre is obtained by dissolving iron or steel in muriatic acid, and mixing the solution with spirits of tar. The following may be given for the mixtures forming the body of lustre ware:—

MASS FOR LUSTRE BODIES.

I.	
Red or brown clay,	20 parts.
Cornish clay,	8 parts.
Blue clay,	4 parts.
Flint,	2 parts.

II.	
Red clay,	50 parts.
Earthenware body,	7½ parts.
Manganese,	1 part.
Flint,	1 part.

III.	
Red clay,	80 parts.
Black Egyptian,	10 parts.

The lead glaze for lustrous ware is usually made as follows:—

Litharge,	60
Felspar,	36
Flint,	15

or other good cream colored glazes.

TILES AND BRICKS.—In considering the formation of the mass, and the subsequent operations by which it is made to assume the required shape, and the degree of hardness desired in this description of clay wares, a similar arrangement and classification will be adopted to that given under POTTERY, properly so called.

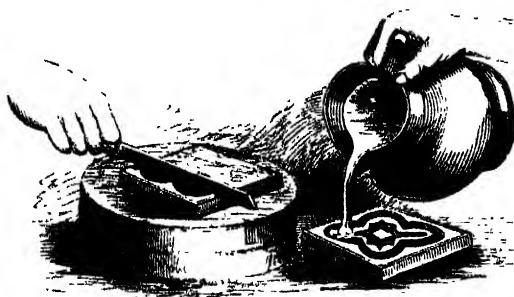
Mosaic, Plain, and Encaustic Tiles, from the superior density and vitreous fracture of the mass, together with the presence at times of a glaze, and the amount of skill and taste displayed in their design, are justly entitled to take precedence in this department of manufacture.

Mosaic Pavements and Inlaid Paving-tiles.—The manufacture of the highly decorative pavements of the mediæval period has, after the lapse of ages, been revived in the art manufactures of this country by the untiring zeal and industry of the late Mr. HERBERT MINTON, under the direction of Mr. M. D. HOLLINS. The chief difficulty in the production of this manufacture is to obtain different colored clays that shall contract and shrink equally during the processes of drying and firing, and without which property it would

be impossible to produce a perfect tile of variegated colors. It is unnecessary to speak of the state of perfection to which these beautiful tiles are now brought, or their fitness for architectural and ecclesiastical decoration. The fine stone body of which they are composed being highly vitreous, and capable of receiving almost any shade of color, renders them peculiarly adapted for such a purpose. The manufacture is extensively carried on by the Messrs. MINTON. The red clay, composing the body of the encaustic tile, is found at Cobshurst, about four miles from Stoke-upon-Trent, and in manipulation receives a facing of a finer clay, to bear the ornamental or colored design, while the back of the tile has a similar layer pierced with holes, the object of which is to prevent the warping of the tile in the fire. The fine clay, composing the ornamental portion of the tile, contracting more in the kiln than the body, would cause it to bend, unless this tendency were counteracted by the layer of similar material placed at the back. The red clay, or marl, previous to working up, is allowed to *weather* by exposure to the air for about half a year. It is then thrown into the mixing vats, as required, and blunged up well with water; after which the clay slip is strained from all impurities by passing it through fine lawn sieves, and evaporated in the slip kiln to the proper consistency for working; or the mass, if for *dry tiles*, is dried into hard lumps, and afterwards ground between mill stones into fine powder, according to the particular processes for which it is intended.

The clay for the body of the encaustic tiles, after wedging and slapping in the usual manner, is shaped into a block in the form of a cube, or parallelepiped, from which the tilemaker cuts off with a wire square slabs nearly approaching in thickness that of the intended tile. These small slabs now each receive the colored facing of finer clay, which is battled out

Fig. 484nn.



and slapped down on their surface. Each tile thus formed is covered with a piece of felt and put into an iron box press of the required size, where it receives pressure upon a plaster of Paris mould having the pattern cut in relief upon its surface. The soft colored clay face thus receives the design, the indentations of which are afterwards filled up with various colored clays. The name of the maker and a few holes to cause adherence to the cement when fixing the tile and also to assist in withdrawing the moisture in the

drying process, are then stamped upon the back, and it is allowed to harden slightly before the next process of firing takes place. The colored materials in the form of thick slip are now poured over the various parts of the indented pattern so as to completely cover the surface—Fig. 484nn. In about twenty-four hours this colored slip is sufficiently hardened to allow of the superfluous clay being removed; for this purpose the tile is placed upon a small whirler, and the pattern brought out by scraping away the clay down to the face of the tile, the cavities only being filled with the colored mixtures. The tile is now properly finished, the edges squared, and all defects corrected; after which it is dried for a week in a warm room before being removed to the stove where the drying process is completed in a period, occupying from fourteen to twenty-one days, according to circumstances. When thoroughly dry the tiles are packed in seggars and fired in the manner described under *Earthenware*, the duration of the baking averaging about sixty hours. The oven is left to cool for six days, after which the tiles are withdrawn in their finished state. The mass contracts in the firing to the extent of one-eighth in every inch. To produce, therefore, an ordinary six-inch square tile, it is necessary to form the model six inches and five-eighths to allow for this shrinkage.

For the formation of encaustic tiles of a more elaborate pattern, the process is varied from that described, the tile being moulded by hand, instead of receiving pressure under a machine, and it is by this manipulation that all the rich and expensive pavements have been produced. These pavements have been introduced in Osborne House, the residence of her Majesty; and under Sir CHARLES BARRY's direction in the House of Lords and the House of Commons; Cleveland, near Maidenhead, the residence of the Duke of Sutherland; and the mansions of most of the nobility, as well as the Senate House, Washington, and St. George's Hall, Liverpool.

Plain self-colored tiles, such as black, red, chocolate, buff, *et cetera*, and also the *tesserae*, are generally termed *dry tiles*, and made of similar material to the encaustic tiles, but subjected to an entirely different process under a method patented by Mr. PROSSER. The prepared clay, after drying upon the kiln till it is quite hard, is ground between stones and reduced to a fine powder; which is afterwards placed upon gypsum slabs slightly damped, and sifted through fine sieves. In this state the quantity required is placed in a strong steel matrix or mould of the size of the intended tile, the bottom surface of the matrix being ribbed, to give a corresponding impression to the bottom of the tile, and cause its adherence more firmly to the mortar or cement in which it may be afterwards embedded, as well as to distinguish the size of tile by the different diapering. Into this matrix, a steel plate with the pattern of the intended tile upon its surface accurately fits, and is brought down with immense pressure upon the surface of the powdered clay, the pressure applied being so great, that the particles are united into a firm solid slab or tile ready for drying and firing. A thickness of three inches of powder will by this compression form a tile one inch thick, sharp in outline, and with a beautiful

polished surface. It is also found that compressed tiles shrink less in the firing than those made from the plastic mass, the former contracting only one-sixteenth in every inch. Many other articles are likewise manufactured by this compressing process, such as scale plates, table tops, furniture panels, *et cetera*, and also with smaller presses and dies, the tesserae for mosaic work, and ornamental buttons for shirt studs.

The number of tiles produced by a single machine is very large, between fifty and sixty dozen being often turned out in ten hours by the labor of one man, while the number of tesserae produced in the same time is scarcely less than from twenty to twenty-five gross.

The celebrated white-glazed tiles which are now so much appreciated for the walls of bath-rooms, dairies, and other domestic comforts, are largely manufactured by this firm under the same process.

Many other descriptions of vitreous paving tiles are also made, and are in large demand for the more ordinary purposes of architectural embellishment. At Tunstall, near Burslem, at the Tillery Works of Messrs. GARRETT Brothers, great improvements have been effected in the form and appliances into which this material can be worked. Hollow pillar shafting of red clay for churches, ventilating ridge roof tiles, and various other applications might be mentioned, as showing the immense field of constructive art into which this material, under skillful treatment, may be carried. In general, the manufacture of tiles being very similar to that of bricks, many of the operations will be described under that section.

Tiles may be classed under three divisions, paving tiles, roofing tiles, and drain tiles, each of which comprehend numerous other varieties. The great distinction between tiles and bricks arises from the greater thinness of the former, and the consequent necessity of increased purity and tenacity in the mass; greater care is also bestowed upon the processes of their manufacture, tiles being always dried under cover.

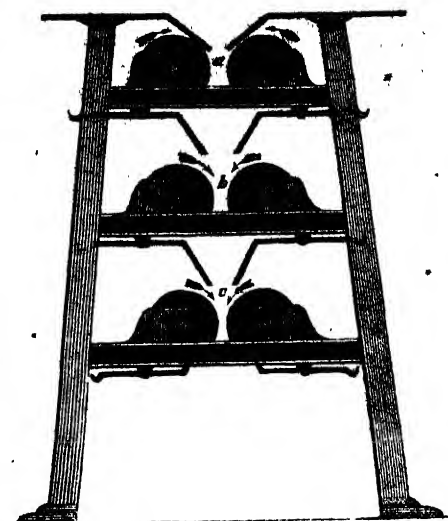
Roofing Tiles are of three kinds—pan tiles, which are of a curved shape; plain tiles, flat and of various shapes, often arranged to form elegant patterns when laid upon the roof; and ridge roof tiles, formed to cope the top of the roof, and often highly ornamental.

Drain Tiles belong to the coarsest class of earthenware, and are of various shapes; sometimes curved over a mould, and sometimes formed by forcing the material through a machine by mechanical means. Other articles, likewise, come under this denomination of wares in their manufacture, such as chimney-pots, tubular pipes for water or drains, and which sometimes require the assistance of the lathe to complete their formation.

Processes of Manufacture.—The marls used to form the mass for working are previously weathered and tempered, the period of exposure depending upon the state of the weather; a frosty atmosphere or a warm sun is more conducive to speedy tempering than a succession of wet and dry days. The marls, when in a proper condition, are taken to the crushing mill—Fig. 48400—where, by passing successively between the sets of rollers, *a, b, c*, through a gradually narrowing aperture, the mass becomes thoroughly pulverized, and

in this state is thrown into layers of the various marls, where it is again weathered, and left for a considerable time to mellow or ripen, and sometimes water is added to hasten this process. It is afterwards tempered and

Fig. 48400.

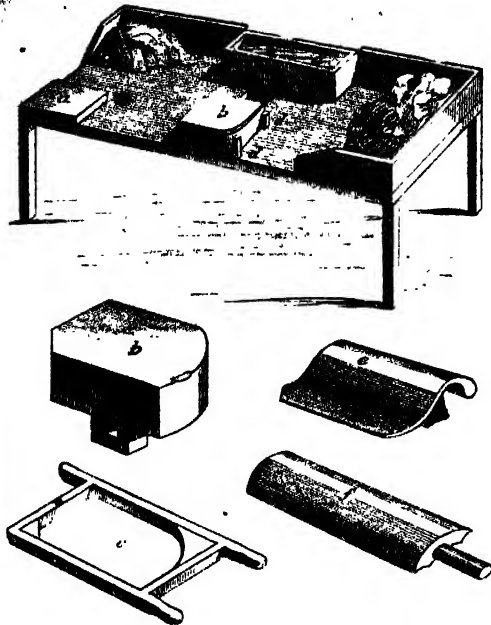


prepared for the moulding processes by passing through the pug mill—see *Earthenware*—from whence it comes oozing out in a mass thoroughly kneaded together and possessing great tenacity. This plastic mass, after separation into blocks or lumps, is conveyed away and stored under cover for future use.

The *moulding* or forming of pantiles is carried on under sheds, the moulding tables being placed on one side, while the remaining space is filled with the *blocks* or drying shelves to receive the pantiles after forming. The prepared clay, after being cut into lumps termed *half pieces*, is brought to the moulding table—Fig. 48400—where the lumps are batted and squared up by an assistant into masses or slabs, *a*, about the size of the mould, and about four inches thick. From this block, by means of a wire, he separates a thin slice the size of a tile, and passes it over to the moulder. The *block* and *stock board*, *b*, for receiving the tile-mould is firmly secured to the moulding table by a strong tenon and mortice; four pegs, *d*, driven into the table at the corners of the block and stock, serve as a support to the mould, *c*, and at the same time regulate the thickness of the tile—five-eighths of an inch. The moulder, having sanded his stock-board and placed his mould on the four pegs, takes the slice of clay from the assistant, and placing it in the mould, smooths the surface with wet hands, and with a brass wire strained upon a wooden bow cuts off the surplus clay level with the mould, and turns the tile out upon the *washing-off frame*, *e*, where it is pressed by the hand into the requisite curved form. It is now struck smartly with the splayer, *f*, and turned over upon that implement for conveyance to the block, where, on withdrawal of the splayer, it is deposited for drying with the convex side uppermost, remaining here for

one or two days. When the tiles are nearly dry they are taken to the *thudding-frame* or horse, the top of which is curved to correspond with the intended outline

Fig. 484rr.



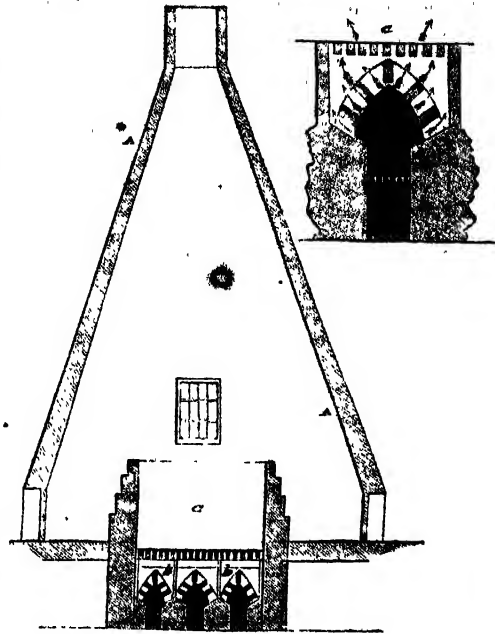
of the tile, and fitted with a wooden block similarly curved. Six or seven of the tiles are now placed upon this horse, and the workman lifts up the wooden block and gives them two or three smart blows, which corrects any warping that may have taken place during the drying process. The tiles are now carried to the kiln.

Firing.—The tile kiln—Fig. 484qq—as constructed in the neighborhood of London, consists of an oven or chamber, *a*, heated underneath by furnaces, *b*, from which the flames circulate freely through the oven by the flues shown in detail at *c*; the whole is inclosed in the brick hovel, *A A*. The time occupies six days, the fires being lighted on Monday morning, and not put out until Saturday evening. The consumption of coal for each firing is about eight tons, but varies with the nature of the goods to be burnt; hollow goods, such as chimney-pots, garden-pots, *et cetera*, requiring less than the more solid wares. These kilns average seventy-five feet in height to the top of the hovel, with an interior diameter of about thirty-six feet; the oven itself being about fourteen feet square by ten feet high.

In the Staffordshire potteries the kiln is of more moderate dimensions; and the fires not being placed in vaults underneath the body of the kiln, are in general protected from the set of the wind by a wall about six feet high surrounding the kiln, and placed at a convenient distance to allow space for the proper regulation of the fires. After the oven is filled, the doorways are built up with bricks daubed over with street-sweepings or clay as a luting; and the fires, after kindling, are burned slowly for the first five hours, after

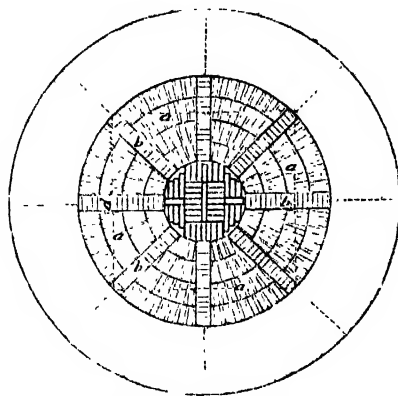
which the heat is progressively increased for the next thirty-three hours; the space of thirty-eight hours being in general sufficient for hard fired blue tiles or bricks.

Fig. 484qq.



The temperature of the kiln is determined by the appearance of the mouths and top outlet of the kiln, as well as by trial pieces. When sufficient heat is attained, and before the fires burn hollow, the mouths are banked up with ashes to prevent the passage of cold air through the oven; and the whole is allowed

Fig. 484rra.



to cool gradually for twenty-four hours before the contents are removed. The operation of firing the kiln generally takes place once a week, and consumes from five to six tons of coal and slack. In charging the oven, the floor is first laid with about two thousand bricks placed edgewise in courses one above the other, *a*—Fig. 484rr— the bricks in the first seven courses being so

disposed as to leave a flue from each fire-place of an average width of seven inches, and the top course, *b*, so as to cover this space, and form the flues. Upon this foundation the tiles are placed in bungs of twelve laid alternately cross and lengthwise; the ribs on the tiles spacing them off, and supporting them in a vertical position. Each side of the square is built up with bricks, *d*, allowing sufficient space in the interstices for

the uniform diffusion of heat through all the goods placed in the oven, a desideratum of the greatest importance in the firing of blue bricks and tiles, and for which the circular form of oven is found best adapted.

The following table gives the analyses of the clays used in the Staffordshire potteries, and found in the district, arranged in the order of their *fusibility*, commencing with the most easily-fusible clay:—

ANALYSES OF CLAYS FROM BASFORD AND THE STAFFORDSHIRE POTTERIES.

	1.	2.	3.	4.	5.	6.	7.	8.
Silicio acid,.....	42.84	51.38	59.44	60.02	64.32	65.78	69.97	70.17
Alumina,.....	17.61	26.55	—	24.26	20.33	15.16	16.79	16.25
Sesquioxide of iron, and a little protoxide,	6.97	—	10.74	9.14	10.86	8.49	8.88	8.41
Protoxide of iron, and a little peroxide,...	—	8.38	—	—	—	—	—	—
Lime,.....	15.36	—	—	1.60	trace	1.67	trace	1.29
Carbonic acid,.....	11.61	3.14	—	—	—	—	—	—
Oxide of manganese,.....	2.20	—	trace	trace	—	—	—	—
Soda, and a little potassa,.....	—	—	—	1.40	—	—	—	—
Water,.....	3.94	7.28	3.11	3.89	6.60	5.37	4.26	5.86
	100.53	99.73	99.22	100.31	102.11	96.47	99.80	101.98

The colors to which the different clays burn in the kiln are given below, the figures corresponding with those of the above table:—

1. Rotten red marl will not stand heat, but fuses.
2. Seggar marl burns *light buff*—a firebrick.
3. Mixture of clays 5, 6, 7, 8, burns *good blue*.
4. Clay from Stoke-upon-Trent burns *red*.
5. Dun-colored marl burns *good blue*.
6. Top-yellow marl burns *reddish blue*.
7. Red marl burns *blue*.
8. Mingled marl burns *blue of a reddish tinge*.

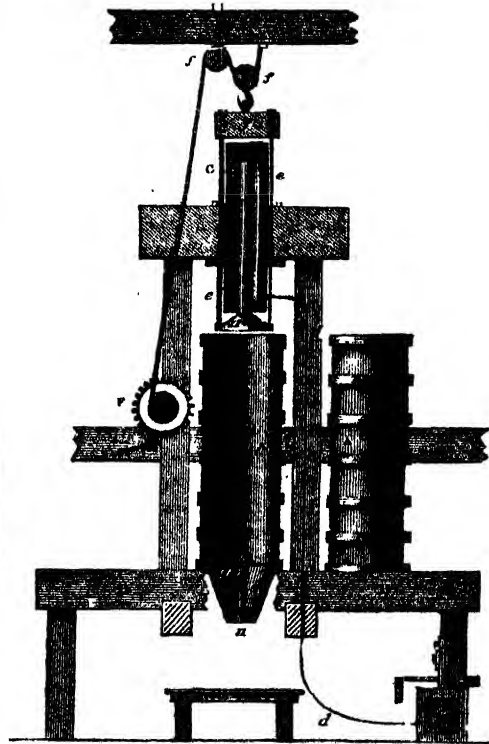
Ornamental ridge and roofing tiles are in general made by a similar process to that described, greater care being required in the moulding and formation of the piece according to the nature of the design; and if this be very elaborate, the tile is sometimes formed of separate pieces united together after moulding, much in the same manner as described under *Earthenware*.

Of late years considerable ingenuity has been exercised in the invention of machines to supersede hand labor in the production of roofing, agricultural drain tiles, water pipes, *et cetera*, all which machines are constructed upon the principle of forcing the prepared clay from a cylinder through a die-plate fixed at one extremity, which delivers the tiles or tubes in the various forms required. As similar machines for the production of bricks will be noticed under that head, it will be sufficient here to describe the method of producing drain pipes by the hydraulic press, carried on at the manufactory of REICHENBECKER, at Ollweiler in Alsace; a process which will at once explain all others of a similar character. The clay mixture to form the pipes, after proper purification, is thoroughly kneaded by passing it between two cylinders revolving at different velocities, which causes them to exert a tearing action upon the mass, the distance between the cylinders being regulated by screws. The mass undergoes a further process, which is necessary before it passes to the moulding apparatus, namely, the expulsion of the minute particles of water retained in the clay by the force of capillary attraction, so powerfully as to resist the action of the press, and which would prevent the

mass from attaining that degree of density necessary to insure its durability and nonabsorbing quality when exposed to constant pressure and the action of liquids.

It is desirable that the mass shall not become too dry, otherwise the process of moulding would be

Fig. 484ss.



rendered difficult; a medium is therefore secured by breaking it up into balls of about eight inches dia-

meter, which are suffered to half dry, and are afterwards repeatedly *slapped* upon a smooth stone to produce a perfectly homogeneous mass. The moulding press—Fig. 484ss—consists of two hollow cast-iron cylinders, *A A*, fixed near each other on a strong movable frame or cradle, *B B*, by which means they can be brought alternately under the ram, *a*, of the powerful hydraulic press, *c*, and which is brought into action by the pump, *e*, and supply pipe, *d*. The rods, *e e*, which are attached to the descending beam, *f*, are for the purpose of raising the ram after each operation, the winch, *r*, and pulleys, *f f*, carrying the rope. The conical moulds, *m*, with the mouthpiece, *n*, for the pipes, are attached to the lower extremities of the cylinders, *A*, and are changed according to the nature of the article to be manufactured. These conical moulds carry the cast-iron mouthpiece, *n*, by the rod, *s*, passing through the centre, and secured into the crosspiece, *g*, cast in one piece with the mould. The plastic mass placed in the cylinder is thus forced by the pressure of the ram through the mouthpiece into the shape of a tube or other article, and is cut by a wire into the requisite lengths, which are removed on a tray to the drying kiln, where they are placed in an upright position upon perforated supports, to avoid as much as possible any bending or want of uniformity in the drying process, a circumstance which would infallibly cause them to split in the kiln. The operation of firing is always one of great risk, as, notwithstanding the care that is taken, the pipes often crack in a longitudinal direction. The application of hydraulic power to the formation of these pipes renders them sufficiently dense and strong to resist a pressure of from thirty-five to forty atmospheres—over one thousand pounds to the square inch—an amount far beyond the capabilities of a pipe manufactured in the ordinary manner. Their diameter varies from one inch to about eight inches, with a proportionate increase in the thickness of the substance. Pipes of a somewhat similar nature, but of larger dimensions, are manufactured by GARRETT Brothers, near Burslem Peake, and others in the locality, at Llwynnion, North Wales, and also at Lambeth, London.

Bricks or artificial stones are intended to replace natural stone whenever this is not to be had, or the hewing and cutting becomes too expensive. Bricks, therefore, are always formed or moulded at once into the required form, varied according to the purposes for which they are intended, such as wall bricks, arch and rectangular or wedge-shaped bricks. These forms never exceed more than a few inches in thickness, on account of the contraction and difficulties attending the drying of larger masses, and they acquire the requisite solidity by burning in the kiln. From the necessary competition into which artificial bricks enter with natural stone, economy in production is an essential point; they are therefore seldom ornamented, and the color is generally confined to the natural hue assumed by the clay in firing. The preparation and purification of the mass are also extremely simple, and are generally performed upon the *field* where the materials are obtained. Bricks, being thicker and more massive than ordinary potters' ware, are necessarily subject to a much greater contraction, and consequent

liability to crack—a defect which is remedied as much as possible by mixing into the mass cheap, noncontractile substances, such as sand, calcareous marl, coal and coke refuse, peat, sawdust, *et cetera*. Sometimes the brick earth contains naturally a sufficient amount of sand or lime, at others the mean quality is obtained by a mixture of clays.

In the neighborhood of London, where bricks are the only material employed for building, the clay is obtained from the alluvial deposits in the London basin that lie above the *London clay*, and consists of layers differing in composition from each other. The lowest deposit containing clay, mixed with fragments of chalk and various gravels, *et cetera*, is rarely used, and passes gradually into the middle stratum termed *malm*, also of clay, but mixed with finer fragments of chalk and sand, in place of the coarse gravel; while in the upper layer the clay preponderates, the gravel and sand being in much smaller quantities, and the proportion of lime is so small that the clay hardly effervesces with acid. This upper stratum is there too fat, and requires to be incorporated with coal cinders or sand, while the middle strata possessing more sand receive only the addition of cinders. Near London and other large towns in England the bricks of the greater number of houses are composed of the earth removed from their foundations. From the uses to which bricks are applied, it is essential that they fulfil certain conditions, as follows:—

Bricks, to be good, must be sufficiently firm and hard to support, without crumbling or giving way, the superincumbent mass they have to sustain, and not be subject to break in carriage.

Bricks must be made so as to withstand pressure, to lie flat upon one another, and have a smooth straight surface free from hollows and cracks.

They must also possess sufficient porosity to admit of a proper degree of adhesion to the mortar, and cause it when dry to form a firm and durable cement.

They must, likewise, possess a hard and uniform structure throughout, so as to afford facility in dressing with the trowel, and not split in contrary directions. They should be able at the same time to withstand changes in temperature, when placed in flues, fire-places, chimneys, *et cetera*, as well as the influences of moisture and frost from external causes.

Some of these necessary qualifications can only be attained by a proper mixture of the mass, and others by attention to the processes of moulding and firing. These varieties of clay are generally incorporated with various substances, such as lime, iron, pyrites, stones, gravel, organic remains, *et cetera*, which, unless removed, are very injurious. Thus when clay containing particles of limestone, chalk, or calcareous petrifications, is formed into bricks, the firing in the kiln converts them into caustic lime, and whenever the water has access to the bricks, and penetrates to these nodules, the slaked lime, expanding, destroys the brick. Iron pyrites is decomposed in the same manner by the fire, and leaves cavities in the mass, giving the brick a greater tendency to fracture in those parts. Vegetal remains, roots, *et cetera*, often occasion the splitting of the bricks dur-

ing firing by the sudden evolution of gas. In the selection and mixture of the clays great care is required; clay, if too *fat*, produces bricks liable to bend and crack in the fire, and with a texture denser and less porous than is required. On the contrary, if the clay is too *poor*, the bricks will be too soft, and easily crumbled to pieces.

The manufacture of bricks may be classified under five heads—*Preparation of Brick-earth, Tempering the Mass, Moulding, Drying, and Firing.*

Preparing the Brick-earth.—The clays, after digging and weathering, as already described under *Tiles*, are classed by the brickmaker into three qualities—*strong clay, mild clay, and malm.* Strong clay in general is sufficiently free from stones to be used for the purposes of brickmaking without washing, but requires that there be mixed with the mass chalk, reduced to the consistency of cream, to counteract the warping and contraction it would otherwise undergo in the process of firing, and to improve the color of the brick. Mild clay has to be passed through the wash-mill, to free it from gravel, and other impurities, before working. The amount of sand present renders it less liable to shrink and warp than the strong clays; but its texture is so loose and incoherent, that a mixture of chalk is necessary to bind the mass together, and to take up the excess of silica in the firing. Malm is an earth suitable for making bricks without any addition, but as it now exists naturally in very limited quantities, recourse is had to the production of an artificial malm by mixing chalk and clay together, previously reduced by passing through the wash-mills. The mixture is run into shallow pits, where, by evaporation and deposit, it becomes of sufficient consistency to be worked up in the subsequent operations. This process, on account of the expense, is only adopted for the best qualities of bricks in the vicinity of London, the mass for commoner kinds being simply mixed together. The object of adding chalk to the clay is twofold—first, mechanical, by diminishing the contraction of the brick; and secondly, chemical, as a flux during the firing, by combining with the silica of the clay. A well-burnt London brick is a silicate of lime and alumina, and differs greatly from an ordinary red fired brick made without lime or alkaline matter, the silica and alumina of the brick earth in this case being only in mechanical, and not in chemical combination. The preparation of the brick earth is much the same process as that described under *Tiles*. In the midland districts the clay is generally ground and crushed between iron rollers, whereas in the vicinity of London the preparation is effected by the wash-mill, and afterwards brought to the proper consistency by evaporation in pits, and *soiled*, or covered with sifted ashes, and left to mellow.

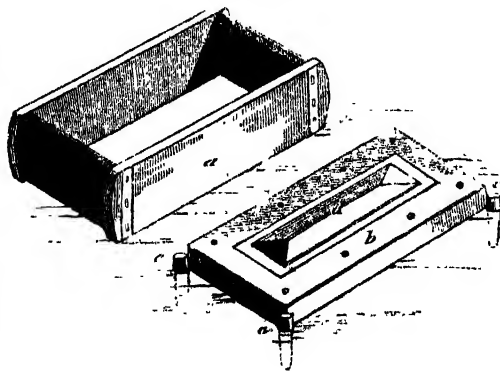
Tempering.—The *tempering* of the mass is performed in various ways, according to the practice of the locality where the bricks are manufactured. The old-fashioned way of tempering by treading consists in spreading out a moderately-thick layer of clay over a wooden floor, and kneading it well over with the naked feet, by which the workman is enabled to detect the presence of stones, roots, *et cetera*; fresh clay and

water are again added, and the operation is repeated until the whole mass becomes so stiff as to impede the action of the feet. Sand, coal-ashes, and similar additions, are sprinkled over the clay and incorporated with the mass, until the whole appears uniformly soft and moist. The extensive demand for brick generally necessitates the employment of machinery, and the *pugging* or *grinding* of the mass takes place in a mill similar to those already described under *Pottery*.

Moulding.—The moulding operation in the manufacture of bricks and tiles is simpler than that of any other kind of clay wares. The workman is supplied with a stock of prepared clay by his side, a small bench or table before him, a tub of water and some dry sand, and an assistant. Two methods of moulding are in use—*stop moulding*, where the mould is dipped in water to prevent adhesion, and *pallet moulding*, where sand is sprinkled over for the same purpose. In *stop moulding* the newly made brick is carried in the mould by the assistant to the *flut* or drying-floor, and whilst this is being done the moulder proceeds with a second mould, the first mould being returned by the time the second brick is ready.

In *pallet moulding* only one mould is used, the brick as it is formed being turned out and placed upon the hackbarrow, and wheeled away to be built into *hacks*, or low walls for drying. The mould is represented in Fig. 484rr; *a* is a four-sided frame of sheet-iron rivetted together at the angles, and strengthened with wood at

Fig. 484rr.



the two sides. The bottom of the mould is detached, and forms what is called the stock-board, *b*, consisting of a piece of wood plated with iron round the upper edge, and filling the mould accurately but easily. Four iron pins, *c c*, are driven into the moulding bench, the stock-board rests upon them, and the thickness of the brick is regulated by their height above the surface. The hollow in the bed of the brick is formed by a piece of wood, *d*, called a *kick*, of the size and shape required, and fastened upon the upper side of the stock-board. The operation of moulding is as follows:—The assistant, or *clot-moulder*, sprinkles the stool with dry sand, and, taking a *clod* or *clot* from the tempered mass, roughly kneads and moulds it into the shape of a brick, and passes it over to the moulder, who having sprinkled sand over the mould, places the clot upon

the stock-board, and dashes the half-formed mass with great force into the sanded mould; the mass which has become flattened by the shock, is forced into the angles of the mould by one or two rapid strokes of his hand; he then, with the *strike*, which has been previously wetted by immersion in the tub, removes the superfluous clay, which is received back by the clot-moulder for reworking. Finally the brick is dexterously turned out of the mould, and conveyed away, while the processes of sanding, *et cetera*, are proceeding quickly for the formation of a second brick.

The number of bricks which a workman can mould in a given time is very great, but depends very much upon the strength and ability of the operator. A moulder with proper assistance will make two thousand bricks in a working day; sometimes a much higher number is attained. The manufacture of the blue facing and paving brick is extensively carried on in Staffordshire; it possesses the same qualities as the blue pipe, ridging, and roofing tiles, and is peculiar to that locality. The annexed tabular statement received from one of the works, and showing the pieces produced there in 1859, will give some idea of the magnitude of the consumption.

STATISTICS OF A BRICK AND TILE MANUFACTORY OF
STAFFORDSHIRE.

Paving quarries,.....	1,000,000
Blue front bricks,.....	150,000
Paving bricks,.....	75,000
Roofing tiles,.....	500,000
Roofing ridges,.....	80,000
Ornamental bricks,.....	150,000
Front red bricks,.....	150,000
Common blue bricks,.....	620,000
Garden edging tiles,.....	25,000
Sanitary tubes,.....	10,000

besides large numbers of other articles not enumerated.

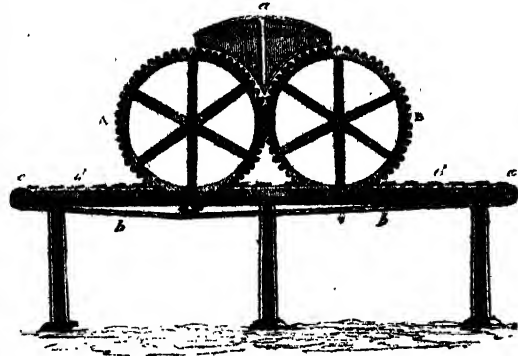
Machinery is sometimes substituted for manual labor in the process of moulding; but from the circumstance of the actual cost of moulding—about one-fourth of a penny for sixteen bricks—bearing so small a proportion to the total cost of brickmaking, it can only be employed with economy in the production of large numbers. The interest of capital, the necessity of keeping a machine constantly at work, and the cost of the motive power which such machines require, demand a very extensive market for the produce. In small brickworks, therefore, machinery effects no actual saving, and is not generally introduced for brick moulding. The mechanical contrivances for producing bricks may be classed under the following denominations:—

1. Machines with actual moulds similar to hand moulds.
2. Machines in which the moulding is performed by several moulds.
3. Machines which cut or stamp out bricks from a cake of clay.
4. Machines which produce a continuous strip or band of clay, and subsequently divide it into separate bricks.

It is unnecessary to enter into the mechanical details or respective merits of these various contrivances; the general principle being easily understood by reference to the machine constructed by Mr. HUNT, and very

generally adopted. A and B—Fig. 484UU—are two cylinders of equal diameter, geared to revolve together, and so placed as to form the front and back of the

Fig. 484UU.



hopper, *a*, the two sides of which are of iron, and arranged to form an opening at the bottom corresponding to the length of a brick, the width being regulated by the distance between the cylinders. When the hopper is filled with tempered clay, the mass forced forward through the opening by the revolution of the cylinders, will have the exact dimensions of a brick. Beneath the hopper, an endless chain, *b*, traverses over the rollers, *c c*, simultaneously with the motion of the cylinders. The pallet-boards, *d d*, are placed at given intervals, to correspond with the thickness of the brick required, and as each pallet-board arrives under the moulded mass, a wire, stretched across a frame, is brought forward and separates the brick, which is at the same time carried onwards by the motion of the endless chain—an operation repeated each time that a pallet-board comes under the hopper.

Drying.—When the bricks placed upon the drying ground in the process of moulding, have become sufficiently firm to be handled without risk of bending, they are set on edge, and piled or *hacked* in the same position until they are six or eight bricks high, spaces being left between them for the free circulation of the air through the dwarf wall thus formed. During the night, or when rain is apprehended, the walls and sides are protected with boards and straw. Sometimes during the process of drying the form of the brick is corrected in any twist by striking with a flat board; a plan that greatly improves the appearance of the brick when price admits of its adoption. Bricks that are intended to be fired in the *clamp*, require to remain in the hacks much longer than those that are fired in a kiln, from the circumstance that the firing in the clamp attains its full heat almost immediately, whereas, on account of the temperature of the kiln being capable of regulation to extreme nicety, the bricks, if *green*, can be dried in the latter by a gradually increasing heat.

An ordinary blue Staffordshire brick, wet from the mould, which weighs twelve pounds four ounces, will

weigh, when fired, only eight pounds one ounce; having lost by evaporation in the drying and burning four pounds three ounces, or thirty-four per cent. of its original weight; the specific gravity being as follows:—

Wet state from mould,.....	2171
Dry state, ready for kiln,.....	2075
Fired state,	1861

The loss in weight of a brick by drying and firing will be further illustrated by the following table:—

1856.	Hours of weighing.	Loss in ounces.	Number of hours between each weighing.	Loss of weight in ounces, during each consecutive twelve hours.
July 13.	7 A.M. weighed 196 oz.			
"	11 A.M. " 191½ oz.	4½	4	} 12 hours day, 27½ oz.
"	3 P.M. " 173½ oz.	18	4	
"	7 P.M. " 169 oz.	4	4	
July 14.	7 A.M. " 163½ oz.	5½	12	} 12 hours night, 5½ oz.
"	11 A.M. " 157½ oz.	5½	4	
"	3 P.M. " 153½ oz.	4	4	} 12 hours day, 10½ oz.
"	7 P.M. " 152½ oz.	1	4	
July 15.	7 A.M. " 150 oz.	2½	12 12 hours night, 2½ oz.

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Total loss by evaporation in drying, previous to firing in the kiln, being twenty-three and a half per cent. of its original weight, and the further loss in firing amounting to fourteen per cent.

Firing or burning is performed in very many different ways, the nature of the fuel which the brick-maker has at his disposal, together with the cost and custom, being all taken into consideration. It is also considerably influenced by the nature of the work, whether stationary or changing to different places; the prices of labor, carriage, *et cetera*, likewise enter into the calculation. The burning of bricks, however, may generally be classed under two methods:—

1st. A *kiln* specially constructed for the purpose, as in the potteries, is used and charged each time with the bricks or tiles to be fired. Such furnaces may be *open, close, horizontal, or vertical*.

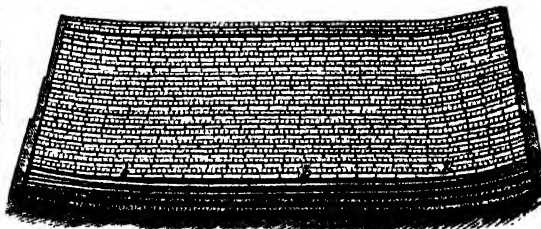
2nd. The bricks are piled one upon another to form a temporary kind of furnace, with the necessary flues; this arrangement is termed a *clamp*, and is well adapted for burning a large number of bricks at once, but not at all suitable for the finer kinds where a sharp outline is necessary.

Kilns, on the contrary, will burn all kinds of bricks and tiles equally well, but, being somewhat expensive in the construction, are only used under certain circumstances. These kilns are similar to a potter's oven, but without bags, or chimneys, or the exterior hovel, the bricks being so placed in the kiln as to form the flues to regulate the heating. In general they average from ten feet to ten feet six inches in diameter; the consumption of coal is about six tons. This construction of furnace is also modified for the firing of the better kinds of goods as well as of the salt glaze sanitary tubes now so generally used throughout England.

The process of burning in *clamps*, the great simplicity of which has given it the preference for general purposes where the locality is so far removed from any kiln as to render carriage too expensive, takes place in the open air; protection being afforded by movable straw hurdles from the too free circulation of air or wind, which might cause combustion to proceed too rapidly in one direction, and put an end to all control over the fires. The clamp, which will often comprise as many as eight hundred thousand bricks, is coated upon the exterior with loam or burnt bricks, and often occupies from eight to ten days in its construction,

according to the number of layers of bricks. Fig. 484vv represents a transverse section of a clamp; the layers of fuel used in firing the bricks, and consisting of

Fig. 484vv.



cinders and small coal, are shown at *b b b*; *liveholes* or flues filled with faggots, and extending through the whole thickness of the clamp, being left to ignite the layers of *brees*, the flames from which permeate the interstices and escape at the top. The firing of a large clamp is commenced by the successive ignition of the liveholes at one end only, and, when thoroughly lighted, the mouths of the whole are stopped with bricks, and plastered over. The proportion of *brees* for firing every hundred thousand bricks, is generally thirty-five chaldrons sifted ash mixed with brick earth, and twelve chaldrons to light the clamp, averaging a cost of ten shillings for every hundred thousand bricks. If the proportion of *brees* is too small, the bricks will be underburnt, tender, and of a pale color; if too much fuel is used, there is danger of the bricks fusing and running into a kind of slag or *clinker*. The length of time of firing varies from twenty, thirty, to even fifty days, according to the size of the clamp. Bricks situated upon the outside of the clamp, and called *turnovers*, are underburnt and placed upon one side for reburning in a future clamp. Bricks situated near the livehole, and exposed to the full intensity of the fire, will be found fused into *clinkers* or *burrs*. Considerable loss occurs in this particular, the clinkers and adjacent bricks being firmly fused together, and attached to the base of the clamp, from whence they can only be removed with crowbars at considerable cost of labor. The loss by fracture, clinkers, *et cetera*, averages about ten per cent. The different qualities of bricks may be known by their color in the firing, and a very important part of the brickmaker's business

consists in sorting the bricks as they are removed from the kiln or clamp. The hard-baked bricks, generally of a dark greyish-brown, are employed for outside work, the well-baked bricks of a red color for walls, while the half-baked yellowish-red or yellow bricks are used for interior work. The harder that bricks are burnt the more sonorous they become when struck, and *vice versa*; they also last longer when exposed to frost than those which are less burnt.

The several descriptions of brick made for the London market may be classified as follows:—

FIRST QUALITY—MALINS.

Cutters are the softest, and used for gauged arches and other rubbed work.

Malins—Best building bricks, used only in fine brickwork; color, yellow.

Seconds—Sorted from the best qualities, and used for fronts of buildings of a superior class.

Paviors—Excellent building bricks, sound, hard, well-shaped, and a good color.

Pickings—Good bricks, but soft and inferior to paviors.

Rough Paviors—Roughest sortings from the paviors.

Washed Stocks—Bricks in common use for ordinary brickwork, the commonest description of malins.

SECOND QUALITY—COMMON.

Grey Stocks—Good bricks, but of irregular color, and not suited for face work.

Rough Stocks—Irregular as regards shape and color, but hard and sound; not suited for good work.

Grizzles—Tender, only fit for inside work.

COMMON QUALITY—INFERIOR.

Place Bricks—Only fit for common purposes, and not for permanent erections.

Shuffs—Unsound and shuffy, full of shakes.

Burns or Clinkers—Used for artificial rockwork, cascades, et cetera.

Bats—Refuse.

Bricks are often adapted in shape to the purposes for which they are intended, either wedge-shaped for arches, round for chimnies, or rectangles of different forms. Sometimes they are constructed as *hollow* bricks, a form which, without impairing their strength, considerably diminishes their weight and cost in transport or carriage. A peculiar kind of brick is made at Berlin from the infusorial clay on the banks of the Spree, a cubic foot of which, weighing in the crude state sixty-one pounds, is reduced by drying and firing to twenty-five pounds seven ounces. Bricks composed of this earth weigh only one-fourth that of ordinary bricks of the same size. Bricks of this material, and containing ten per cent. of clay, were used for building the Museum in Berlin. Infusorial earth forms an admirable cement for clay in place of sand.

FIRE-CLAY goods are employed either for smelting,

as *crucibles*, or as *fire-bricks*, for lining furnaces, et cetera; their fire-proof qualities depending upon the amount of heat to which they are intended to be exposed, as a brick that would withstand the temperature of a limekiln may fuse in the heat of a porcelain furnace, and even those that withstand the highest temperature attained in manufactures will be fused, and frequently volatilized before the oxyhydrogen blowpipe, or between the poles of a powerful galvanic battery. As the success of smelting, and other operations in which high temperatures are required, depends so much on the material employed in the construction of the furnaces, and other apparatus, a general inquiry into this subject becomes necessary.

The fusibility of a substance is not solely influenced by the elements which enter into its composition, but also by the manner in which these elements are arranged and combined together. The chief constituent of clay—alumina—is a base which, in combination with silica, forms one of the most refractory substances, and this property is possessed by the clays in proportion as they are unmixed with other bases, as alkalies, oxide of iron, lime, and magnesia, in the order here given. In the purer clays, which for all ordinary purposes may be considered fire-proof, the refractory quality is augmented in proportion to the quantity of silica they contain.

In procuring fire-proof material, it is always desirable to obtain a chemical analysis; for, although this cannot supersede an actual trial, it is of the greatest service in guiding to the selection of the materials required to be added, in order to produce in the material the required properties. Such additions are generally necessary, as fire-clay must not only be infusible at the temperature to which it is exposed, but likewise free from liability to crack or fly, properties most important in the construction of *crucibles*. The chief cause of cracking is *contraction*, and this must be lessened by the addition of substances which do not themselves shrink, and at the same time do not impair the refractory nature of the clay. Pure sand, ground and free from lime and iron, and fire-clay previously burnt, are the substances most usually and appropriately employed. When fire-clay is brought into contact with substances exerting a chemical reaction upon it, and decomposing it by acting as a flux, it is much more difficult to obtain a ware capable of withstanding the combined action of heat and chemical affinity. An analysis of the most noted fire-clays employed in the construction of crucibles and fire-bricks is given in the annexed table:—

	Place of manufacture	Silica.	Alumina.	Oxide of iron.	Magnesia
Crucibles from	Gross Almerode	71	25	4	—
"	Paris—Beaufays	65	34	10	—
"	Saveignies, near Beauvois	72	19	4	—
"	England, for casting steel	71	23	4	—
"	St. Etienne, for casting steel	65	25	7	—
Glass pots from	Nemours	67	32	1	—
"	Bohemia	68	29	2	trace

Fire-clay wares require to be more strongly fired, in order to acquire an equal degree of solidity with those of ordinary clay—a circumstance partly occasioned by the large quantity of cement which enters into the composition of the mass. It is also of importance that the

wares acquire their maximum hardness and full amount of contraction before they are used. Crucibles do not always require firing, as is the case with the Passau crucibles, which are simply dried. Hessian crucibles, on the other hand, are burnt at about the same heat as

ordinary stoneware. The following table, according to BERTHIER, gives the elementary composition and rela-

Dried at 100° centigrade.	Gross Almerode.	
	Berthier.	Salvetat.
Hygrometric water	—	0.43
Combined water	15.2	14.00
Silica	46.5	47.50
Alumina	34.9	34.37
Oxide of iron	3.0	1.24
Lime	—	0.50
Magnesia	—	1.00
Alkali	—	trace

Glass pots and retorts for the production of gas are, perhaps, the largest vessels at present constructed of fire-clay. The fire-clay retorts constructed by Messrs. JOSEPH COWEN and Company of Blaydon Burn, near Newcastle-upon-Tyne, are sometimes as long as ten feet, with an internal width of three feet, and are constructed in one piece. In use they are found to be four times

	1.	2.	3.	4.	5.	6.	7.
Silica	51.10	47.55	48.55	51.11	71.28	83.29	69.25
Alumina	31.35	29.50	30.25	30.40	17.75	8.10	17.90
Oxide of iron	4.63	9.13	4.06	4.91	2.43	1.88	2.97
Lime	1.46	1.34	1.66	1.76	—	—	1.30
Magnesia	1.54	0.71	1.91	trace	2.30	2.99	—
Water and organic matter ..	10.47	12.01	10.67	12.29	6.94	3.64	7.50

By this it will be seen that the amount of silica in No. 2 is to the total amount of the bases as 100 : 85, while in No. 6, it is as 100 : 16. These clays are mixed together in certain proportions according to the purposes for which they are intended. The clay is not suspended in water, the coarser particles being ground into the mass, together with the addition of one-fourth part in weight of sawdust. The gas-retorts require to resist the sudden changes of temperature, which they undergo in the processes of firing and recharging, and average three inches in thickness to give them durability. These circumstances, combined with the Π form of the retort, would inevitably cause them to crack, if the mass was not rendered excessively porous by the destruction of the sawdust in the firing. Powdered coke may be used for the same purpose, while the loss of gas from the porosity of the mass is prevented by the layer of carbon deposited on the interior surface during the operation. The retorts are either moulded and built up by hand with the plastic material, or formed by pressure in machines, somewhat similar to those described for pipe-making, but under pressure so enormous as sometimes to rend asunder iron cylinders between two and three inches thick. The drying and burning proceeds afterwards very slowly to avoid all chances of bursting of the retort when in use. The firing lasts fourteen days, and the retorts are of a pale-yellow color.

Newcastle-upon-Tyne also carries on an extensive trade in the manufacture of fire-bricks from the same clays above enumerated, and the preparation of which is as follows:—The clays, after exposure to the atmosphere for some time, are removed to the clay-mill, and ground up with fragments of the same clay previously burnt, from whence it is taken to the pug-mill for mastication before it is taken to the moulder. The bricks are then laid out to dry, and afterwards burnt in a kiln about fifteen feet long by fourteen feet broad, and ten feet high. Each kiln will burn

tive proportions of the constituents in several kinds of smelting crucibles:—

Beaufort, Department des Ardennes.		Hriery Hill, near Stourbridge.		Schierfort, near Fosse.	
Berthier.	Salvetat.	Berthier.	Salvetat.	Berthier.	Salvetat.
19.0	10.3	17.34	16.50	0.50	—
52.0	63.7	45.25	45.79	—	—
27.0	20.7	28.77	28.10	—	—
2.0	4.0	7.72	6.55	—	—
—	—	0.47	2.00	—	—
—	—	—	—	—	—

as durable as iron. The material which furnishes these fire-proof wares consists of seven varieties of clay belonging to the coal formation, and which are found in the neighborhood of Newcastle-upon-Tyne. They occur below the coal, and are worked with them from the same pit. In color they are greyish-brown and full of vegetal remains. The analysis is as follows:—

about fifteen thousand bricks at once. The operation of firing lasts five days. The bricks are placed on their edge lengthwise in the kiln. Stone-bricks of a very valuable kind, and used in the construction of the arches of reverberatory furnaces employed at Swansea in smelting copper-ores, are extensively manufactured at Neath in Glamorganshire. The materials of which the bricks are composed, are obtained from the neighborhood; they are subjected to a coarse crushing process under an edge-stone, and after mixing with a little water, are compressed into form by a machine, the coarseness of the mass rendering the moulding by hand impossible. This brick is fired in the ordinary way, but resists the action of intense heat better than the Stourbridge clay-brick. It expands more by heat, and does not contract to its original dimensions. The analysis of the three materials composing the mass is as follows:—

	From Penderyn.	From Dinas	
Silica,	94.05	100	91.95
Alumina, with traces of oxide of iron,	4.55	traces	8.05
Lime and magnesia,	—	traces	traces
	98.60	100	100.00

These bricks may therefore be called *siliceous* or *stone bricks*, and will no doubt prove admirably adapted for the construction of many kinds of chemical furnaces. A red fire-brick is likewise manufactured at Windsor, the analysis of the clay from which it is prepared being as follows:—

Silica,	84.65
Peroxide of iron,	4.25
Alumina,	8.85
Lime,	1.90
Magnesia,	85
	100.00

Or in mechanical mixture about seventy sand, and thirty parts clay.

QUININ.—*Quinia* or *quina*.—This important substance, which was discovered by PELLETIER in 1820, is found naturally in the bark of several species of *cinchona*, which inhabit the Eastern slopes of the Cordillera in Bolivia, Peru, and New Granada. Three principal species of bark occur in commerce—the yellow, true, or Calisaya bark, obtained from *cinchona cordifolia*; the red, yielded by *c. oblongifolia*; and the pale, from *c. condaminea*. It is found, also, though in smaller quantities, in a variety of barks, which are nearly all obtained from trees of the same family, the distinctive characteristics of which are but imperfectly known.

In the bark, quinin is associated with cinchonin, cinchonidin, cinchoninic, all possessing more or less basic attributes; kinic acid; cinchona red, which occurs in two forms, soluble and insoluble; a yellow and a green coloring matter; besides starch, gum, and lignin. The quinin exists partly as kinate, and partly in combination with cinchona red.

CONSTITUTION AND PROPERTIES.—Quinin is one of the more powerful organic alkalies. It generally appears, when pure, as an amorphous, resinous mass, of a dull white color. Its formula is— $C_{20} H_{24} N_2 O_4 + 6 \text{ aq.}$ It may also be obtained in six-sided prismatic crystals, which are a hydrate, containing six equivalents, or 10.5 per. cent. of water, which are lost on fusion.

Quinin has an intensely bitter taste; it is inodorous, and fuses readily. It dissolves sparingly in boiling, and still more sparingly in cold water. It is easily soluble in ether and in alcohol, especially if hot, and is also soluble in the essential and fixed oils.

Ammonia decomposes the salts of quinin in the cold; but on the other hand, at the temperature of ebullition the ammoniacal salts are decomposed by this alkaloid. Tartaric, oxalic, and gallic acids, and the infusion of nut-galls, precipitate solutions of its salts. Quinin menstrua, if treated with chlorine gas, become yellow, rose-red, violet, and finally deposit a red resinous matter. A solution of the sulphate, saturated first with chlorine and then with ammonia, acquires a grass-green color, and deposits a green powder. With tincture of iodine, the solution yields a clear brown liquid, which on concentration deposits saffron-colored scales of a new compound. To detect small quantities of quinin, precipitate the suspected liquid with calcined magnesia, and evaporate to dryness; then extract with one part alcohol and two parts ether. Evaporate again to dryness, and extract with ether. Now prepare a test liquor, by saturating boiling water with ferridcyanide of potassium, to which, whilst hot, are added five volumes of the strongest chlorine water, and then ammonia, until the blackish-green liquid becomes very alkaline, when the sediment is filtered off. Now mix the fluid to be tested with excess of chlorine water, and drop in the test liquor. A blood-red color indicates the presence of quinin.

Or, put a minute particle into a watch-glass, drench it with five or six drops of pure sulphuric acid and an equal quantity of water, and add a fragment of bichromate of potassa. If quinin is present, the mixture will first assume a green shade resembling that of arseniate of copper, then a beautiful yellow green, and finally a

dark green. The sulphate, similarly treated, becomes first a nickel green, next a copper green, and finally a dirty-yellow. The above-mentioned reaction with chlorine and ammonia may also serve for the detection of quinin. Quinin combines with the acids, forming a series of well-defined and persistent salts, of which the sulphate is the most important.

SULPHATE OF QUININ, usually called the *disulphate*, $HIO, C_{20} H_{24} N_2 O_4, SO_3 + 7 \text{ aq.}$, crystallizes in small silky tufts, or in fine acicular prisms; it has an exceedingly bitter taste, and when heated becomes phosphorescent. The dry salt is composed of one equivalent of quinin, one of sulphuric acid, and one of water. In the crystalline state it takes up, in addition, seven more equivalents, or 14.4 per cent. of water. It effloresces in dry hot air. It dissolves in thirty parts of water at 212° Fahr. , but is very soluble in alcohol, especially with the aid of heat.

PREPARATION.—Quinia is generally prepared as sulphate.

The bark to be operated upon is in the first place submitted to a preliminary examination, in order to ascertain the amount of alkaloid which it contains. The safest method is to take about two pounds of bark, and to treat this by the common process for the preparation of sulphate of quinine.

GUILLERMOND proposes the following process for testing bark:—reduce the bark to powder, and treat this in a displacement apparatus with ten times its weight of alcohol of eighty per cent. Add to the alcoholic product thirty grammes of powdered quicklime for every two pounds and a quarter of bark, and agitate the mixture repeatedly. By this operation the liquor is almost completely decolorized. Filter off the sediment of lime, and add to the filtrate sulphuric acid, enough to produce the very faintest acid reaction. Distil off the bulk of the liquor, filter off the slight resinous precipitate, and concentrate the filtrate to crystallization. Others exhaust two ounces of the bark with eight ounces of water, and one scruple sulphuric acid. The mixture is kept for twenty hours at a temperature of 140° , and filtered. The digestion is twice repeated with similar quantities of acid and water. Mix and add ammonia as long as anything falls; filter, wash, dry, and weigh the precipitate. A prompt, though less accurate test, is the precipitation of a decoction of the bark by means of an infusion of nut-galls, the amount of alkaloid in the bark being estimated from the greater or less amount of the precipitate formed. The ordinary procedure for obtaining quinin is to exhaust the bark with dilute sulphuric acid, boil the extract with milk of lime, and extract the precipitate thus obtained with alcohol, from which, on concentration, the crude alkaloid separates in crystals. These are redissolved in dilute sulphuric acid, and purified by treatment with animal charcoal and recrystallization. A more perfect, though less rapid process, is as follows:—Pound the bark coarsely and let it steep in water, to which one-fifth of an ounce of hydrochloric acid has been added for every two pounds and a quarter of bark employed. Next morning boil the mixture for two hours, and strain. Submit the bark to a second and a third decoction in water containing

only half the above proportion of acid. Make, finally, a fourth decoction in pure water, and keep this for the first acid decoction of a fresh quantity of bark. The bark may now be thrown away. Mix the acid liquors, heat, and add carbonate of soda in slight excess, allowing the precipitate which forms to subside. Decant off the supernatant liquid, and test it by means of ammonia. Should this reagent produce a precipitate, the liquid must be precipitated once more with carbonate of soda. The whole precipitate is placed on a linen filter, and left to drain. It is next pressed and dried at a gentle heat. When perfectly dry it is reduced to powder, and treated from five to eight times with alcohol of eighty-six per cent., at the heat of the water-bath; squeeze the grounds each time, and filter the alcoholic liquors. The alcoholic fluid contains quinin and cinchonin, with coloring matters and some fatty substances. It is next very slightly acidulated with weak sulphuric acid, distilled, and the residue allowed to cool in the distillation apparatus.

A crystalline mass appears, which is drained on a linen cloth, to get rid of the black mother liquor. It is then washed with a little water. Make the crystalline mass, which is still highly colored, into a paste with warm water; mix with this animal charcoal in powder, and leave the paste till next morning. Mix the paste with a suitable quantity of water and boil, taking care to carry the concentration sufficiently far to obtain crystals upon cooling. For this purpose, it is preferable to divide the paste into several portions, and to treat them separately. Filter the liquid boiling. Upon cooling, the sulphate of quinin separates in perfectly white crystals. At the end of forty-eight hours let the mother liquor drain off, place the crystalline mass on some double folds of paper arranged on a hurdle, and carry them to the drying stove, taking care to keep the salt covered, since otherwise it would turn yellow. As soon as dry the salt must be removed from the stove, or it will effloresce and lose weight. The mother liquor which had deposited the white sulphate is next precipitated with ammonia, which throws down all the quinin and cinchonin still contained in it. Dissolve the precipitate with the aid of heat, in water acidulated with sulphuric acid, and add, towards the end of the operation, animal charcoal, and, if necessary, a little chalk to saturate the excess of acid. Seethe the liquid to a proper degree of concentration, and filter boiling. A fresh crop of white crystals will be deposited from the filtrate.

Treat the mother liquor of this second operation in the same way, and continue to proceed in this manner until the whole of the alkaloid is converted into crystallized sulphate. After the third precipitation it is sometimes advantageous to treat the precipitate with alcohol of sixty-four per cent., which dissolves the quinin alone, instead of dissolving it in water acidulated with weak sulphuric acid. A part of the alkaloid still remaining in the mother liquor is deposited spontaneously as sulphate, in course of time, and may be purified by the usual method. To extract the quinin still remaining in the mother liquor, the following process has been proposed by GUMBOUT:—Add to the black mother liquor an equal weight of a solution of chloride

of sodium of 15° Beaumé. Boil for ten minutes, decant, and submit the brown deposit which has been formed twice more to the same operation. Pour the decanted liquors together, cool and filter, and precipitate the filtrate with ammonia. Redissolve the brown deposit which had separated from the saline liquid in the third operation in water, and add gradually, and in small portions at a time, ammoniated salt-water, taking care to stop short of complete saturation. Filter the liquid off the soft brown precipitate which forms, throw the latter away, and precipitate the filtrate with ammonia. Treat the several ammoniacal precipitates with alcohol. The solution, treated in the usual way, will now yield sulphate of quinin.

The quantities of sulphate of quinin furnished by the varieties of bark which occur in commerce are:—Two pounds eight ounces of yellow, or Calisaya bark, without rind, yield four hundred and ninety to five hundred and thirty grains sulphate of quinin. The same quantity, with the rind, yields three hundred and sixty grains. Two pounds eight ounces of the red bark, *c. oblongifolia*, will yield two hundred and forty-eight grains sulphate of quinin, besides about half that quantity of sulphate of cinchonin. Two pounds eight ounces of pale bark should yield one hundred and eighty grains sulphate of quinin, and one hundred and twenty-four grains of sulphate of cinchonin.

The following process, which has been patented by Mr. HERRING, yields a product not indeed perfectly free from color, but nowise inferior in its medical properties, and at least twenty per cent. cheaper than the common sulphate of quinin. Hence it is designated by the inventor *hospital sulphate*:—

First Operation, without Alcohol.—The powdered bark is boiled in a solution of caustic soda, pressed, returned to the boiling tub, agitated with cold water, again pressed, and if much color passes from the second washing the bark is returned to the tub, washed again with cold water and pressed once more. The treatment of the liquors obtained by the soda boilings and washings is described under the second operation. The decolorized bark is now boiled with dilute sulphuric acid, kept in constant agitation by proper machinery, and this first boiling is run into the evaporating pan, a large water bath kept by steam pipes at a temperature of 120°, and agitated by the paddle wheels. The bark is again boiled with sulphuric acid and water as above, and the liquid run into the evaporating pan. The third, fourth, and fifth boilings are not evaporated, but reserved to extract the next portion of decolorized bark that is brought forward. When the liquor from the first two boilings is sufficiently concentrated, it is allowed to cool, and filtered. Thus the flocculent coloring matter is separated, and the acid solution is now fit for precipitation. The filtered cold solution is treated by caustic soda, and the precipitated quinin is drained, washed, and pressed. It is now treated with dilute sulphuric acid, and crystallized into a very thick paste. When cold these crystals are pressed, washed, and again pressed. This removes the coloring matter and the chief part of the sulphate of cinchonin. The pressed cakes of sulphate are finally dissolved in a large quantity of water and recrystallized. The crystals

thus obtained from the hospital sulphate of quinin. The liquid which drains away from the second crystallization removes the small quantity of cinchonin which may not have been got rid of by the first crystallization. If the sulphate is required perfectly white it is redissolved, treated with *pure* animal charcoal, and again crystallized.

The patentee believes that in the ordinary method of making sulphate of quinin *impure* animal charcoal is absolutely necessary, though there is of course the risk of contaminating the product with the salts of charcoal.

Second Operation, with Alcohol.—The blood-red soda-boilings of the bark mentioned in the first operation are treated with hydrochloric acid, in order to retain in solution the alkaloids which have been extracted by the alkaline boilings. The ordinary view that quinin is insoluble in alkalies is pronounced erroneous by the patentee, who states, that in acting upon large quantities of bark the amount retained in solution is very considerable. The caustic alkalies exert less solvent power than the carbonates, and caustic soda least of all. After the red alkaline liquor has been acidulated with hydrochloric acid, it is concentrated and precipitated with lime. The precipitate, a mixture of quinin and lime, is washed, dried, and powdered, and finally extracted with hot alcohol. On distilling off the alcohol, the crude alkaloids are left behind. These are then treated with dilute sulphuric acid, exactly as in the former process, a larger quantity of water being required for removing the coloring matter and the sulphate of cinchonin. After two more crystallizations the sulphate is obtained perfectly pure.

The first operation yields from eighty to ninety per cent., and the second from ten to twenty per cent. of the required product.

Uses.—Quinin is now very extensively employed in medicine as a tonic and febrifuge. For these purposes it is used in combination with sulphuric, citric, or valerianic acid. The double citrate of iron and quinin is likewise very often prescribed.

ADULTERATIONS.—The consumption of this important remedy having greatly increased, whilst the superior varieties of cinchona bark are becoming yearly more scarce and costly, it is naturally subject to a great variety of adulterations. Amongst these may be enumerated chalk, sulphate of baryta, gypsum, boracic acid, gums, sugar, sugar of milk, starch, stearin, margarin, salicin, and phloridzin. Besides these intentional impurities, cinchonin and quinidin may be present if the preparation has not been conducted with due care. Phosphate of lime is also occasionally found, derived from the animal charcoal used in decoloring the alkaloid.

Mineral impurities may be detected by incinerating a portion of the sample in a platinum capsule. *Pure* quinin leaves no residue. Or a portion of the suspected quinin may be treated with alcohol at a gentle heat. Quinin dissolves, whilst any mineral matter which may be present, as well as gum, starch, stearin, will remain untouched. If a portion is burned upon platinum foil, sugar and margarinic acid may be detected by their peculiar smoke and smell.

Sugar may likewise be detected by dissolving a known weight of the sample in water, and adding baryta, which precipitates both the quinin and sulphuric acid, if present. Any excess of baryta is now removed by a current of carbonic acid gas, and the liquid filtered and concentrated, when sugar, if present, is at once known by its taste. Gums and sugars may also be detected as follows:—Dissolve a weighed amount of the sample in water, and add a solution of pure carbonate of potassa, which precipitates both quinin and cinchonin. The precipitate may be filtered off, carefully dried, and weighed. Sugar and gum remain in solution. The liquid is now evaporated to dryness at a gentle heat, and the residue treated with weak spirit of wine, which dissolves the sugar, leaving gum intact. Filter off the clear liquid, and dissolve any residue in hot water. The aqueous solution is then tested with the sesquisulphate of iron, which precipitates gum as a yellowish jelly. If the sample is boiled in water, and the solution allowed to cool, starch may be detected by adding an aqueous solution of iodine, when the well-known blue or black tinge will appear. Starch, gum, and sugar may also be recognized on placing a little of the suspected sample in a porcelain capsule, and moistening with concentrated sulphuric acid. Quinin is merely dissolved, whilst starch, gum, and sugar are blackened. Ammoniacal salts are detected by titrating a portion of the sample with liquor potassæ, when an ammoniacal odor is evolved. If phloridzin is present, the sample turns a greenish-yellow in contact with sulphuric acid, and is discolored by the vapor of ammonia. If salicin be present to the extent of ten per cent. and upwards, the sample will turn a deep blood-red on the addition of concentrated sulphuric acid. In smaller proportions it may be detected by dissolving the sample in about six times its weight of concentrated oil of vitriol, and then adding twice the amount of water, when the salicin is precipitated, and may be filtered off and tested with sulphuric acid. If cinchonin be present the sample is dissolved, mixed with ammonia in excess, and well shaken up with ether. Quinin is dissolved, whilst cinchonin remains untouched, and may be separated by filtration.

The ordinary organic impurities may be detected by the following simple experiment:—A very small quantity is heated upon platinum foil, or in its absence, upon a silver spoon to fusion. *Pure* quinin has then the appearance of oil of sweet almond; the *pure* sulphate a pale ruby red, the citrate a pale lemon or a deep yellow, if excess of acid be present. The valerianate remains unchanged in color. If adulterated, the residue will have neither polish nor transparency, and will be black and porous. The detection of the remaining cinchona alkaloids, if present in the salts of quinin, is more difficult. When submitted to optical tests, quinin and cinchonidin, according to BOIRCHARPAT and PASTEUR, are powerfully levogyrate; quinidin and cinchonin pre-eminently dextrogyrate; and quinicin and cinchonin slightly dextrogyrate, upon plane-polarized light.

The ordinary tests for quinin, as mentioned above, distinguish between that alkaloid and quinidin on the one hand, and cinchonin, cinchonidin, and cinchonin on the other.

Oxalate of ammonia, when added to a solution of these alkaloids gives, after some hours, a crystalline precipitate of oxalate of quinin—if the liquid contain not less than one part of alkaloid in eight hundred of water—and a white precipitate in strong solutions of cinchonin. It does not precipitate cinchonidin or quinidin.

If hydriodic acid or iodide of potassium be added to neutral solutions, the following distinctions appear on crystallization:—The hydriodate of quinin appears as lemon-yellow prisms; the corresponding salt of cinchonidin in long thick colorless prisms; the hydriodate of quinidin in short hemihedral prisms; and that of cinchonidin in silky colorless prismatic needles.

RESINS.—*Resines*, French; *Harze*, German.—These are proximate principles found in most vegetables, and in almost every part of them; in some of them the quantity is very insignificant, whilst in others the resin is found in such abundance, as to render its extraction for industrial or medicinal purposes a profitable business, and it is to the latter class that the following particulars and descriptions apply. They are obtained chiefly in two ways; either by spontaneous exudation from the plants, or by extraction by heat and solvents. In the first case the discharge of the resin takes place, in the liquid state, from accidental punctures in the bark of the tree or shrub containing it, and also from artificial incisions penetrating the bark nearly to the hard wood. The substance which issues from these apertures is not a pure resin, but a mixture of it with volatile oil and other matters. In summer or the warm season the exudation flows freely, and the volatile oil being partly driven off spontaneously and partly resinified, the residue acquires considerable hardness. Should any of the volatile body remain, however, it is driven off on boiling the crude matter in water, and thus the resin is obtained free from all volatile oils.

When the coldness of the season prevents the flowing of the resinous body, the method adopted for its extraction is somewhat as follows:—The ligneous matter impregnated with the resin is reduced by rasping or grinding as fine as possible, and the powder boiled with strong alcohol. Many other matters besides the resin are thus extracted, and, on adding water to the spiritous extract, partly precipitate with it. By a fractional distillation of the menstruum most of the alcohol is recovered; and during the ebullition the finely-divided particles of resin collect and agglomerate in the aqueous fluid.

Resins possess the following general properties:—They are soluble in alcohol, insoluble in water, and melt by the application of heat, but do not volatilize without partial decomposition. They have rarely a crystalline structure, but, like gums, they seldom affect any particular form. They are almost all translucent, not often colorless, but generally brown, occasionally red or green. Any remarkable taste or smell which they sometimes possess, may be ascribed to foreign matter, commonly an essential oil. Their specific gravity varies from 0.92 to 1.2 Their consistence is also very variable. The greater part are hard, with a vitreous fracture, and so brittle as to be readily pulverized in the cold. Some of them are soft, a circum-

stance probably dependent upon the presence of a heterogeneous substance. The hard resins do not conduct electricity, and they become negatively electrical by friction. When heated they melt more or less easily into a thick viscid liquid, and concentrate, on cooling, into a smooth shining mass, of a vitreous fracture, which occasionally flies off into pieces like Prince Rupert's Drops; especially after being quickly cooled, and scratched with a sharp point. They take fire by contact with an ignited body, and burn with a bright flame and the diffusion of much fuliginous smoke. When distilled by themselves in close vessels, they afford carbonic acid and carbides of hydrogen, empyreumatic oil of a less disagreeable smell than that emitted by other such oils, a little acidulous water, and a very scanty shining charcoal.

The solution of resins in either hot or cold alcohol reddens tincture of litmus, but not sirup of violet; it is decomposed by water, and a milkiness ensues, out of which the particles of the resin gradually agglomerate. In this state it contains water, so as to be soft and easily kneaded between the fingers; but it becomes hard and brittle again when freed by fusion from the water. The resins dissolve in ether and the volatile oils, and, with the aid of heat, combine with the unctuous oils. They may be united by fusion with sulphur, and with a little phosphorus. Chlorine bleaches several colored resins if they be diffused in a milky state through water. The sulphide of carbon dissolves them. Concentrated mineral acids decompose resins under the influence of heat, the agents being likewise reduced. Strong sulphuric acid dissolves them in the cold; but on the addition of water, they again separate without decomposition. When heat is applied the sulphuric acid is broken up into sulphurous acid; at the same time carbonic acid results from the resin, and a carbonaceous residue with the artificial tannin of HATCHELL remains. Nitric acid aided by heat effects several transformations in resin, according to its state of concentration and the period during which its action is continued. Some resins yield, to this treatment, oxalic acid, and invariably artificial tannin may be obtained.

Most of them dissolve in solutions of the fixed alkalies, whether hot or cold, as also in ammonia, and form definite salts—resinates—some of which are quite neutral. These resinates are soluble in water, and form a considerable portion of the cheaper kinds of soap, being themselves possessed of detergent qualities. Resinates of the alkaline earths, and of the heavy metallic oxides, may be prepared from those of the alkalies by double decomposition; but they are insoluble, and generally strong acids liberate the resin from them unchanged.

Every resin is a natural mixture of several others, which sometimes admit of easy separation by different solvents, such as alcohol, ether, essential oils, alkaline solutions, *et cetera*. For instance, when certain acid resins are dissolved in alcohol, and an alcoholic solution of acetate of copper is added, it happens sometimes that only a part of the resin is precipitated. The deposit, which can be readily separated from the liquid, is found occasionally to be but partially dissolved by

other menstrua, and consequently admits of being separated into several definite substances. Again, many resins on being treated with a solution of potassa, soda, or ammonia, do not entirely dissolve; and inferring from this that the undissolved portion has not the same properties as that dissolved, the conclusion follows that two or more distinct principles were contained in it. The soft resins, which retain a certain portion of volatile oil, constitute what are called balsams, a full description of which will be found in Vol. I., page 224, *et sequitur*.

According to DUMAS the resins may be arranged in five classes, namely:—

1. Those which yield a volatile oil on being distilled with water, and leave an acid resin, or rather several resins possessed of acid properties, in the retort. To this class belong the several turpentine resins, balsam of copaiba, *et cetera*.

2. Those which yield a volatile oil when distilled with water and one or more acid resins, as in the foregoing; but in addition, a neutral one, generally capable of being crystallized. Animi, elemi, and caranna resins, mastic, vegetal, or palm wax, and several others, are of this order.

3. Resins which do not furnish a volatile oil on being distilled with water. Such are copal, aniber, lac, betulin, and the like.

4. Resinous matters containing substances soluble in water of the nature of gum. Many of the members of this group have been already described as gum-resins, under GUMS, to which the reader is referred.

5. Balsams or compounds which contain, besides a volatile oil and an acid resin, cinnamic or benzoic acids, or some substances capable of producing them. It will be unnecessary to follow the description of the subjects coming under this class here, as they have been already described at some length.—See BALSAMS.

The Editor will now glance cursorily at each variety of resin in its alphabetical order, space not permitting of more.

AMBER.—*Succin*, French; *Bernstein*, German; *Succinum*, *Electrum*, Latin.—This interesting substance is frequently included among minerals, with which, however, it can no more be classed than the resin copal found in the sands of Africa. It is a substance of vegetal origin, resembling copal and other resins in appearance, and in some of its physical and chemical properties, and, like them, is employed for varnishes. The variation of its properties from those of ordinary resins is not, perhaps, greater than is to be found among the different members of the class, and may be in part attributed to a slight and gradual alteration effected during the time of its exposure to the various natural agents. From some of its chemical and physical properties and its occurrence in or near coal or lignite, it is usually supposed to be a resin derived from trees of the same geological age with the upper, secondary, or tertiary strata; but from the formation of succinic acid from fat, as well as from amber, one might suppose it to have been a species of wax, or to have a fatty nature. Its balsamic or resinous origin is more probable than the latter view. According to the traditions of the ancient Celtic nations, amber signifies tears shed by

APOLLO on leaving heaven for the famed Hyperborean island—Erin—and the account is thus happily recorded by BRYANT:—

The Celtic sages a tradition held,
That every drop of amber was a tear
Shed by APOLLO when he flew from heaven;
For sorely did he weep, and, sorrowing, passed
Through many a doleful region, till he reached
The sacred Hyperboreans.

Amber is most abundantly found on the Prussian coast of the Baltic, Courland, Livonia, Pomerania, and in Denmark, where it is often washed up on the shore by the waves, after the autumnal storms; or it is dragged up by a net, or obtained by mining. In the latter case a stratum of sand, then of loam, are pierced, neither containing amber; but below the latter occurs a bed of lignite, in and near which it is obtained. From the cones found near it, one may attribute the amber to the balsam of certain extinct species of coniferæ, which has hardened by the loss of its volatile oil. It frequently contains insects of various genera and species; among them several genera of spiders, no species of which is now in existence. Some genera of these insects are still found in South America and New Holland, but the species are extinct; and but a single living insect found in America has been observed in amber, namely—*Iepisma saccharinum*. It is sometimes, but rarely, found on the Scandinavian coast; other localities are Hasen Island, Greenland, near London in sand, and Paris in clay, in Italy, on the Sicilian coast, in Spain, Siberia, China, and the United States, where it occurs in the red clay formation subjacent to the green sand, and sometimes in the green sand itself.

Thus it occurs frequently associated with lignite on Martha's Vineyard; from Amboy to below Camden, New Jersey; in the clays and sands of the deep cut on the Delaware and Chesapeake Canal, and in the green sand in Delaware; further at Cape Table, Maryland. It is said that Prussia draws an annual revenue of seventeen thousand rixdollars from this substance.

It is found of variable sizes; a specimen in the royal collection at Berlin weighs eighteen pounds. It is sometimes colorless, though usually some shade of yellow, light and brownish yellow, reddish-orange, brownish-black; it is transparent, translucent, opaque, sometimes milk-white and opaque, different hues and degrees of transparency occurring in the same piece; it has a resinous lustre, is rather brittle, has a conchoidal fracture, and a soft-feeling shining surface; it receives a good polish, and hence is carved into ornaments.

Specific gravity 1.065-1.075. By friction on woollen cloth it becomes strongly negatively electric.

Heated in the air it fuses at about 549°, evolving an agreeable aromatic odor, and burns with a clear flame. By fusion it is decomposed and its properties altered, giving off volatile matter and leaving a clear brownish translucent resin, which is almost insoluble in alcohol, partially soluble in ether, and most perfectly in fixed and volatile oils, with a brownish-yellow color. Slowly heated in linseed oil to boiling, it is soft and flexible, without fusing or decomposing, and, unless cooled slowly in the oil, is as brittle as glass; opaque spots are thus often rendered translucent.

Amber is wholly insoluble in water; absolute alcohol and ether become yellow in contact with it; when used on the substance powdered they extract succinic acid and resin.

It is soluble, with a brown color, in strong sulphuric acid from which water precipitates the greater part of a yellow color, which retains a little of the acid; by boiling with the same acid tannin and charcoal are produced. Nitric acid changes it to a yellow resin, which gradually dissolves in the acid. Finely powdered, and boiled with solution of caustic or carbonated alkali, much succinic acid is removed; and pure water extracts a resinat of the alkali from the residue, leaving amber bitumen.

By destructive distillation in a closed vessel an acid liquor containing acetic and succinic acids passes over; some crystals of succinic acid are then deposited in the neck of the retort, after which an empyreumatic oil is disengaged, at first thin and yellowish, but subsequently brown and thick; finally, a light-yellow wax-like sublimate appears in the neck of the retort, to which BERZELIUS has given the title of *crystallized pyréline*, and GMELIN amber-camphor. The proximate constituents of amber are a volatile oil, succinic acid, two resins soluble in alcohol and ether, and a bituminous insoluble substance which constitutes the chief bulk of it; its ultimate analysis showed it to consist of carbon, hydrogen, and oxygen in the following proportions:—

	Centesimally.	
	Draesler.	Ure.
Carbon,	80.59	70.68
Hydrogen,	7.31	11.62
Oxygen,	6.73	7.77
Ash,	3.27	9.93
Loss,	2.10	
	100.00	100.00

USES.—Fine amber is used for making trinkets and ornamental objects; but its estimation is much greater in this respect in Oriental nations than with Europeans. The portion designed for ornamental work is split on a leaden plate on a lathe, and then smoothened to a shape on a Swedish whetstone; it is then polished with chalk and water or vegetal oil, and finished by rubbing with flannel. In these processes the amber is apt to become highly electrical and very hot, so much so as to produce nervous tremors in the wrists and arms of the workmen from the electricity. The artists guard against these effects, however, by working the pieces in rotation, so that the heat may not increase to an injurious degree, and the amber remains only feebly excited. The coarser kinds of amber are employed in chemical and pharmaceutical operations, and also for the manufacture of varnishes.

ANIME.—A resin not unlike copal, and of which there are two varieties, the American and the Oriental. The American anime is said to flow from incisions in the *hymenaea courbaril*, a tree growing in Brazil, Virginia, and the West Indies. The purer resin occurs in pale yellow pieces, with a vitreous fracture and dusty surface; softens in the mouth, tastes like mastic, and has an agreeable odor, especially when heated; specific gravity 1.03; combustible, and gives a lively flame. Warm oil of olives or lavender dissolves it;

it is wholly soluble in boiling alcohol, the solution reddening litmus, although the acid is scarcely extracted by water. Cold alcohol separates it into two resins; the soluble—54.3 per cent.—resembles the resin itself; the difficultly soluble resin—42.8 per cent.—precipitates from a boiling alcoholic solution, drying to a tasteless mass, slightly odorous and lighter than water. It also contains about 2.4 per cent. of a volatile oil, which passes off by heating *per se*, or with water. A brown variety does not soften in the mouth.

The Oriental anime, which has a specific gravity of 1.0272, appears to be a mixture of two resins, one pale-yellow, brittle, not softening in the mouth; the other reddish-yellow, softer; it does not contain the difficult soluble resin, and its alcoholic solution has a less acid reaction. It is not decomposed by nitric acid, even at the heat of fusion.

Anime was formerly employed in pharmacy, but is now chiefly used for scenting pastilles, and for varnishes; but it is rather a bad material for the latter, as it is dried with difficulty, and leaves the coating soft and pasty. For these reasons it is never used *per se*, but in admixture with other more suitable resins.

Botany Bay Resin, said to be the produce of *acarois resinifera*, is of a yellow hue, brittle, and of a slightly astringent taste. It exhales a fragrant odor when heated, and dissolves in alcohol and ether. It resembles tolu balsam in containing cinamic, and a small quantity of benzoic acid.

COLOPHONY.—*Common Rosin*.—This is the residue remaining on the distillation of common turpentine; it retains more or less water, and is known as white and yellow resin, being in this state translucent, and often slightly viscid. When deprived of water by fusion, it is termed brown or black resin, colophony, rosin, or fiddler's rosin.

Rosin is a brittle, tasteless, and almost inodorous substance, of a smooth shining fracture; its specific gravity is 1.080. It softens at 150°, but does not enter into fusion under 275°. According to the analysis of BLANCHET and SELI, this substance, in its pure state, may be represented as composed of $C_{40}H_{70}O_4$; but UNYERDORFEN has shown that colophony includes two distinct acid resins, together with a minute portion of an indifferent one. These acid resins he designates pinic acid, and silvic acid, the former greatly preponderating. As respects the composition of these acids, it appears that they are isomeric, and therefore have the same formula as that above ascribed to pure colophony, a conclusion sanctioned by ROSÉ and TROMMSDORFF, but not by LÖWIG.

Rosin forms an important ingredient in the composition of yellow soap, and is a partial substitute for fixed oil or fat; it is not analogous to the latter in chemical constitution, nor can it, like those bodies, form with an alkali a proper soap by itself. Colophony contains no glycerin, nor any equivalent for that substance.

The formation of yellow soap from rosin depends on the direct combination of the resin acids with soda. No glycerin is eliminated, there being no proper saponification. The compounds formed, however, by the union of soda with rosin are not separable from their

aqueous solutions by chloride of sodium, like true soda soaps, nor do their concentrated solutions become mucilaginous or gelatinous on cooling, nevertheless they produce a lather, and, when added to soap in limited proportion, increase its detergency. Rosin is also used to some extent in perfumery.

This resin is largely employed in manufacturing industry for the purpose of extracting the various oily bodies it produces by destructive distillation, and which oils are largely consumed in the arts, as well alone as for adulterating dearer kinds. The bleaching of common colophony has long engaged attention, but success did not attend the various efforts. Latterly, however, Messrs. HUNT and POCHIN's patent seems to have accomplished the task of converting the common black resin, worth four to five shillings per hundredweight, into a white almost transparent compact article, which is said to be highly beneficial to soap and varnish makers, and worth as much as fifteen shillings per hundredweight.

Their process may be here advantageously although cursorily described. It consists in distilling resins and resinous substances without decomposition, or only partially so, by which they are freed from various mechanical impurities, and at the same time almost deprived of their color. The ordinary rosin of commerce, *et cetera*, are taken and introduced into an iron or other suitable vessel; they are then melted, and steam is passed, during the entire period of the operation, through the fluid mass, until the whole, or nearly the whole, has been distilled. The rosin is condensed in a suitable receiver, kept as cold as it can be by the application of water, and exsiccated; it is then adapted for the purposes for which it is required. During the distillation the temperature rises from about 390° to 600°, at which it is maintained until all such portions of the contents of the still as are capable of being volatilized have passed into the receiver. Instead of steam, carbonic acid, or a mixture of carbonic acid and nitrogen, or hydrogen gas or carbides of hydrogen, are introduced to decolor the resin.

COPAL, said formerly to have been derived from *rhuss copallinum* and the *eleocarpus copalifer*, seems by late accounts to be obtained from various species of *hymenaea trachylobium* and *ronapa*. Several varieties of this resin are known in commerce, which are apparently the product of different trees, natives of Africa, America, the East Indies, and New Zealand. Levant copal is considered the best, and is met with in moderate-sized round masses, hard, transparent, colorless, or but slightly lemon yellow. *It is, of all resins, that which makes the finest varnishes.* Two kinds of copal resin are known; one hard or true, and the other tender or fictitious copal. The true variety, as above stated, is met with in large pieces, colorless, or of a slight yellow shade, exteriorly opaque, but limpid in the interior. In some cases its tint approaches to a brown. Insects are occasionally found inclosed in it, but more rarely the debris of plants.

It has so much resemblance to amber that it might be supposed to have a fossil origin; at all events it has probably been long exposed to the action of the air before being collected. It is very hard, and breaks

with a conchoidal fracture. Exposed to heat it softens, but does not permit its being drawn into threads; when the temperature is more elevated it melts, and at the same time undergoes decomposition, and distributes on boiling a vapor having the peculiar odor of the wood of the aloe tree. Its specific gravity varies from 1.045 to 1.139. In the natural state copal is only slightly soluble in absolute alcohol; on boiling it, however, it tumefies, and forms a viscous elastic mass; with ether it acts in a similar way, but ultimately dissolves. When it is desired to dissolve it in alcohol *per se*, the best method is to suspend it in the vapor of the boiling liquid, and it gradually falls drop by drop and is perfectly dissolved; with oil of turpentine, under similar treatment, the result is the same. To avoid the loss of spirit and other inconveniences which attend this process, many trials have been made. One of these, though singular, is said to be effective; it is to grind the resin and expose it to the air for a period of ten or twelve months, after which it is readily taken up by spirit of wine. It may be dissolved in absolute alcohol by first acting on it with ammonia, which softens it into a gelatinous mass, and then adding the spirit in small portions, with the aid of heat. It may likewise be dissolved in alcohol after being softened with ether.

The ordinary practice is, however, to take advantage of the property which certain essential oils have of softening the resin, and thereby rendering it more readily soluble. A quantity of the copal is taken and moistened with oil of rosemary or of lavender; after standing for a time some pieces begin to soften, while others are unaffected; the former are selected for spirit varnish, and the latter are put by for varnish to be made with fixed oils. The first portion is then ground, moistened a second time with either of the essential oils named, and after a short time it swells up to a pasty mass, which on addition of the necessary quantity of spirit of wine dissolves. Spirit of turpentine behaves in like manner. The same menstrua, provided a little camphor be first dissolved in them, readily take up the resin, but the varnish thus formed, as also that prepared by means of oil of rosemary, is soft and devoid of the durability which the real spirit varnishes made with the resin possess. But the common copal varnish is made by melting it cautiously, and adding oil of turpentine heated to a certain point.

According to UNVERDORPEN and FILHOL, who have more recently examined Indian copal, it contains no less than five definite compounds of a resinous nature, four of which possess acid and one neutral properties. Thus, in treating powdered copal with a spirit containing sixty-seven per cent. of alcohol, and adding to the extract thus obtained an alcoholic solution of acetate of copper, a precipitate of bluish flocculi appears, which on being dried and affused with cold ether takes up resin A; the alcoholic liquid retains resin B in solution. Further, on treating the residue with absolute alcohol, a third resin, C, is dissolved together with portions of the two preceding ones; and, finally, by treating what remains from the last menstruum with potassa, a fourth resin, D, separates, and a neutral substance, E, remains.

The analysis of copal, according to FILHOL, is as follows:—

	Bombay copal	Madagascar copal	Calcutta copal
Carbon,.....	79.70	79.80	80.66
Hydrogen,...	9.90	10.78	10.57
Oxygen,.....	10.40	9.42	8.77
	100.00	100.00	100.00

The composition of the resin alters, however, on being exposed to the air for some time in a finely-powdered state, or when reduced to an impalpable powder by abrasion under water, oxygen being absorbed, as the following analyses illustrate:—

	Copal exposed to the air in fine powder	Copal reduced to an impalpable powder under water.
Carbon,.....	77.0	71.4
Hydrogen,.....	10.0	9.2
Oxygen,.....	13.0	19.4
	100.0	100.0

Tender or fictitious copal is found in commerce mixed sometimes with a little Indian copal, but it is brought from the Brazils without any admixture. That from India is vitreous, translucent, and nearly as transparent as glass, but age communicates to it a shade of yellow on the surface. Its ordinary form is in tears; it possesses a weak, agreeable odor, is very friable, and preserves this property even in the varnish made with it, on which account it is not so much esteemed. Heat renders it soft and elastic, so that it can be drawn out into threads as fine as silk. Alcohol partly dissolves it, the residue appearing like gluten. Ether takes up nearly the whole substance.

FILHOL has analyzed this resin and found it gave—

Carbon,.....	85.3
Hydrogen,.....	11.5
Oxygen,.....	3.2
	100.0

Dammara Resin is a white resin brought from the East Indies, and is said to be the produce of the *pinus dammara*; it contains a resin soluble, and one insoluble in alcohol.

Dragon's Blood, which is a deep-red resin imported from the East Indies, has been fully described, although erroneously, under BALSAMS, in vol. i., page 227.

ELEMI.—It appears that the source from which this resin is obtained is very doubtful. It is generally described as constituting a member of the *Amyrideae*, which is allied to the class to which the orange-tree belongs, owing to LINNÆUS confounding apparently two distinct plants under one name—the *amyris elemifera*—namely, the *icica icicariba* and the *amyris plumieri* of DE CANDOLLE; the former a Brazilian tree which yields, according to PISON, a resin similar to the so-called *gum-elemi*, and the latter a native of the Antilles, which likewise produces a resin. PEREIRA, in tracing the source and origin of this resin, found that it was imported entirely from Amsterdam and Hamburg, and concluded that it was the product of a Dutch settlement. He is inclined to believe that which formerly came from Ethiopia by way of the Levant was derived from the *canarium zephyrinum* or *canari*

barat of RUMPHIUS, who says that it yields a resin so like elemi that it might be taken for it. PEREIRA mentions three kinds of elemi—elemi in flag leaves, elemi in lumps, and Brazilian elemi. The first is imported into England from Holland in triangular masses of one to two pounds weight, enveloped in palm leaves. The elemi in lumps is a little paler in color than the Brazilian. MARTIUS states that the first variety is the product of the *amyris seylanica*; though PEREIRA doubts the assertion, on the ground that if it were a product of Ceylon it would be imported direct hither, which is not the case. The only doubt which he seems to throw upon the Brazilian elemi being derived from the *icica icicariba*, which may be taken for the *amyris elemifera* of LINNÆUS, rests upon the certainty of its being a Brazilian product.

In extracting the Brazilian elemi, an incision is made into the stem of the tree, whence the juice exudes, and the resin is gathered in twenty-four hours afterwards. It is imported in cases containing two or three hundred pounds each. It is soft and unctuous, but becomes hard and brittle by cold and age. It is semitransparent, of a yellowish-white color, mixed with greenish points; its odor is strong, agreeable, analogous to that of fennel. This is owing to a volatile oil, which may be obtained from it by dry distillation.

The description most extensively dealt in, is that which is brought to this country from Singapore in a soft, strong-smelling mass, in cases of about two hundredweight. It is the produce of Manilla, and the Editor is credibly informed that it is not imported from any part West of Singapore. In addition to this, the Brazil sort is occasionally seen in the market.

The proximate principles of elemi are a transparent resin having acid properties, soluble in cold alcohol; a second resin taken up by boiling alcohol, but deposited from the solution on cooling in a crystalline state; a volatile colorless oil, which, according to DEVILLE, resembles much the essence of turpentine, and of citron in composition, as in its reactions; and a bitter extractive. The annexed per centages were found by BONASTRE:—

Volatile oil,.....	12.5
Resins soluble in both hot and cold alcohol,...	60.0
Resins soluble in hot, but not in cold alcohol } —elemi,.....	24.0
Bitter extractive,.....	2.0
Impurities,.....	1.5
	100.0

The resin *a*, readily soluble in cold alcohol, consists, according to JOHNSTON, of $C_{40}H_{82}O_4$, while the resin *b*, sparingly soluble in cold alcohol, is composed of $C_{40}H_{82}O$. Specific gravity, 1.08 BONASTRE; SCHUBART gives it 1.055.

Elemi is occasionally used as a topical remedy in the form of an ointment, more particularly in ulcerous complaints of an old and indolent nature. It is extensively employed for varnishes.

GUAIAACUM.—This substance, which is commonly, though very erroneously, denominated gum-guaiaicum, is the produce of the *guaiacum officinale*, a lofty tree, native of St. Domingo and Jamaica. It occurs in tears naturally exuding from the stem; and in lumps ob-

tained partly from incisions into the trunk of the tree, and partly by the action of heat upon billets of the wood. This resin is of a dark-green dingy color, transparent when in thin laminae, and of a brilliant resinous fracture. It has a slight balsamic odor. Its powder is at first pale grey, but gradually deepens, and becomes green by exposure: it acquires a beautiful but transient blue tint when moistened with spirit of nitrous ether. According to the Edinburgh Pharmacopoeia, the characters of guaiacum resin are as follows:—Fresh fracture red, slowly passing to green; the tincture slowly strikes a lively blue color on the inner surface of the paring of a raw potato. The specific gravity of guaiacum varies between 1.20 and 1.23. It is soluble to the extent of about ninety per cent. in absolute alcohol. The insoluble portion, though sometimes described as resin, has more of the characters of altered extractive. When subjected to dry distillation, guaiacum fuses at about 570°, and an oily matter, together with water, passes over, which has been examined by SOBRERO, and by PELLETIER. When chewed, guaiacum softens under the teeth, but has scarcely any taste, though it leaves a burning sensation in the throat.

Physiological Effects.—Guaiacum resin is an acrid stimulant, formerly very much used in medicine, and even now to a great extent.

Under the use of small and repeated doses of guaiacum various constitutional diseases sometimes gradually subside, and a healthy condition of the system is brought about with no other sensible effect of the remedy than perhaps the production of some dyspeptic symptoms, and a slight tendency to increased secretion. One designates this inexplicable, though not less certain, influence over the system by the term *alterative*. When guaiacum is given in *moderately large doses*, or to plethoric, easily excited individuals, one observes the combined operation of an acrid and stimulant. In very large doses guaiacum causes heat and burning in the throat and stomach, vomiting, purging, pyrexia, and headache. In its operation on the system guaiacum is allied to the balsams.

JALAP.—The resinous portion of jalap is the most important. Jalap resin is obtained by mixing the alcoholic tincture of jalap, prepared by percolation or digestion with water. The precipitated resin is to be washed with warm water, and then dissolved in alcohol. By evaporation the tincture yields the resin. PLANCHÉ has proposed another process. By digestion with animal charcoal, the alcoholic solution of the resin is rendered nearly colorless, and by evaporation yields an almost colorless resin. Jalap resin is soluble in alcohol, but insoluble in water. Triturated with milk it does not form an emulsion, but its particles unite into a solid mass. By this it may be distinguished from scammony resin.

Physiological Effects.—Jalap resin is a local irritant. It acts as a powerful and drastic purgative. To scammony it is closely allied, not only by its effects, but also by botanical affinities and chemical properties. It is much less irritant to the intestinal mucous membrane than gamboge; and, therefore, is a much safer purgative.

Adulteration.—Commercial resin of jalap is rarely,

if ever, obtained in a state of purity. Guaiacum resin is the substance most frequently found mixed with it. Two methods have been pointed out for detecting this fraud—one by means of ether, the other by nitrous gas. Ether dissolves guaiacum very well, but does not dissolve resin of jalap. With nitrous gas the process consists in dissolving a small quantity of the suspected resin in spirit of wine, soaking a piece of white paper in this liquid, and exposing the paper to the action of nitrous gas. If the alcoholic solution of resin of jalap contain guaiacum, the paper should assume a blue tint; if no guaiacum be present, the color will remain unaltered.

MASTIC is the produce of the *pistacia lentiscus*, native in the South of Europe, the North of Africa, and the Levant, particularly the Island of Chios. It occurs in small spheroidal translucent tears, of a pale yellow hue, vitreous fracture, agreeable odor, and mild aromatic taste. When chewed, it becomes tough and somewhat viscid; it fuses at about 250°, and begins to be decomposed; it contains a very minute quantity of volatile oil. Mastic is a valuable ingredient in certain varnishes, and is frequently used for the purpose of stopping decayed teeth. It is not employed in medicine. Its produce is commonly known under the name of *opoponax*.

SANDARACH, or Juniper resin, is the produce of *thuja articulata*, which grows in Barbary. It is imported from Magadore, and largely used as an ingredient in varnishes. It usually occurs in small yellow brittle drops, easily fusible, and soluble in alcohol.

SCAMMONY RESIN.—The substance known in pharmacy under the name of *scammony*, is an exudation from incision of the root of the *convolvulus scammonia*, and appears first as a milky juice, which afterwards dries. It is often very considerably adulterated. Several varieties of this drug come into the market, but the most select is imported from Smyrna, and occasionally from Trieste, under the name of *virgin* or *luchryma scammonia*. It is of a dark-greenish grey color, moderately hard, and of a somewhat resinous fracture. It should not effervesce with hydrochloric acid, nor should its cold filtered decoction be blued by iodine. One hundred grains, when incinerated with nitrate of ammonia, should not yield more than about three grains of ashes: ether should abstract from it at least seventy-eight per cent. of resinous matter. The odor of scammony, especially when breathed upon or moistened, is peculiar; and when a little water is rubbed upon its surface it should easily lactify.

THE RESIN OF SCAMMONY, obtained by evaporating its ethereal solution, is transparent, and of a brown tint, but may be decolorized by animal charcoal. Its alcoholic solution is feebly acid, and water throws down from it the resin in the state of hydrate. According to JOHNSTON, it is remarkable as containing more oxygen than any other resin hitherto analyzed. It is a powerful cathartic.

LAC.—*Laque*, French; *Gummilack*, German.—This resin is produced by the female of a small insect—the *coccus lacca*, or *coccus ficus*—which feeds and fecundates upon the banyan or religious tree of the Hindoos, and several allied plants, such as the *ficus indicus*, *ficus*

religiosa, the *rhamnus jujuba*, the *croton lacciferum*, and the *butea frondosa*.

In November or December the young brood makes its escape from the eggs lying beneath the dead body of the mother; they crawl about a little way, and fasten themselves to the bark of the shrubs. About this period the branches swarm to such a degree with the vermin that they seem covered with a red dust, in which case they are apt to be dried up and exhausted of their juice. Many of them, however, adhering to the feet of birds, become their prey, and are carried off by them to other trees. They soon produce small nipple-like incrustations upon the twigs, their bodies being apparently glued by means of a transparent liquid, which goes on increasing to the end of March, so as to form a cellular texture. At this time the animal resembles a small oval bag, without life, of the size of the cochineal. At the commencement a beautiful red liquor only is perceived, afterwards eggs make their appearance. In October or November, when the red liquor becomes exhausted, twenty or thirty young ones bore a hole through the back of their mother and come forth. The empty cells remain upon the branches; they are composed of the milky juice of the plant which serves as nourishment to the insects, and which is afterwards transformed into the red tinctorial matter which is found mixed with the resin; but its quantity is greater in the body of the insect than in the eggs, and more particularly in the red liquor secreted for feeding the young. After the escape of the insect the cells contain much less coloring body, and, consequently, the collection of resin ought to take place before that time by breaking off the twigs and drying them in the sun. In the East Indies this operation is performed twice in the year—the first time in March, and the second in October.—*Ure*.

The dried branches and twigs are called *stick-lac*, which serves the double purpose of dyeing, varnish-making, and sealing wax.

There are several varieties of stick-lac. According to quality that of Siam is considered the best, the Assam stick-lac ranking next, and the third quality is produced in Bengal. The analyses of the stick, seed, and shell lac are here collated:—

	John Stick-lac.
An odorous resin,.....	66.65
Resin insoluble in ether,.....	16.75
“ laccin,.....	
Coloring matter,.....	3.75
Laccic acid,.....	0.62
Extractive,.....	3.92
Skins of insects,.....	2.08
Wax,.....	1.67
Salts,.....	1.04
Sand,.....	0.62
Loss,.....	2.90
	100.00

	Hatchett.		
	Stick-lac.	Seed-lac.	Shell-lac.
Resin,.....	68.0	88.5	90.9
Coloring matter,.....	10.0	2.5	0.5
Wax,.....	6.0	4.5	4.0
Gluten,.....	5.5	2.0	2.8
Foreign bodies,.....	6.5	0.0	0.0
Loss,.....	4.0	2.5	1.8
	100.0	100.0	100.0

Lac as brought to Europe is in various forms, such as grains, lumps, and thin scales; the former is called *seed-lac*, and is the residue after the resinous matter scraped off the stick-lac, ground and boiled in water to remove the greater part of the coloring matter, and dried in the sun; the second is called *lump-lac*, and is merely the former melted into lumps; and the third, which is named *shell-lac*, is of the same nature as the seed and lump-lac, only purer. It is usually prepared in India by heating the seed-lac in bags over a fire, and by squeezing and pressing, causing the liquefied resin to flow out and fall upon the smooth surface of the stems of the banyan-tree; the coatings thus formed on cooling harden and constitute shell-lac.

It will be seen from the preceding tables that the proportion of resin is much larger in shell-lac than in any of the other commercial forms of the resins. The better quality of the article is of a light-brown hue passing into orange, and sometimes to a deep ruby color, whence the names *orange* and *ruby* shell-lac; the inferior kinds are much less transparent, darker in color like glue, and in thicker plates.

By exposure in thin shreds to the sun's rays, or in a finely-divided state to chlorine water, or by reducing it to a fine powder, suspending in water and passing hydrochloric acid vapor into the menstruum, the dark-colored varieties are bleached. When this is done, however, the resin loses many of those qualities that so admirably recommend it for some kinds of varnishes, but it answers well for making sealing-wax.

Lac resin is very difficultly soluble in alcohol, though, like copal, it may be completely taken up by this solvent. Like most of the other resins, it has a strong affinity for bases, with which it forms definite compounds. Dilute hydrochloric acid and acetic acid dissolve the resin freely, but not the strong sulphuric acid. Borax solutions with the aid of heat also take it up. The portion soluble in alcohol has a specific gravity of 1.139. UNVERDORPEN found it to be a compound of several resins, namely—

1. Resin soluble both in alcohol and ether. 2. Resin soluble in alcohol, insoluble in ether. 3. Resin but very slightly soluble in cold alcohol. 4. Crystallizable resin. 5. Resin soluble both in alcohol and ether, but not in petroleum uncrystallizable. Besides these, a saponifiable fat wax and coloring matter have been detected in shell-lac.

SILVER.—*Argent*, French; *Silber*, German; *Argentum*, Latin.—This is one of the precious metals, and is characterized by its perfectly pure white color. Its combining weight is 108; its symbol, Ag. Melted, its density is 10.47; hardened under the hammer, it becomes 10.54. Its specific heat is 0.057. In malleability it is only inferior to gold, and may be beaten into leaves of less than one-hundred-thousandth of an inch in thickness, and drawn into very fine wires. It has also considerable tenacity, a wire of one-hundredth of an inch in diameter supporting a weight of twenty-three pounds. It is harder than gold, but softer than copper, and when pure it is so soft as to be cut by a knife. The addition of a small quantity of copper increases its hardness.

Silver melts at a full red heat, corresponding to

1870°; but in consequence of its pure white color, and the high lustre which it is capable of receiving, its reflecting power for light and heat is greater than that of any other metal, and, therefore, when perfectly polished, it does not melt in the focus of a mirror capable of fusing platinum. For the same reasons, its radiating power is so low that a silver vessel retains the heat of a liquid contained in it longer than a vessel of any other metal.

HISTORICAL NOTICE.—The discovery of silver appears to have been coeval with that of gold, and dates back to the earliest times of human history. In the book of Genesis it is stated that ABRAHAM, who lived about two thousand years before the Christian era, was rich in cattle, and in silver, and in gold; and on the death of his wife he purchased a field for a burying-place, the payment for which was made with four hundred shekels of silver, which he delivered not in coin, but *by weight, according to the currency of the merchants*. JOSEPH, the great grandson of ABRAHAM, was sold by his brethren to a caravan of Arabian merchants for twenty pieces of silver; and when he was established in Egypt as minister of the king of that country, his brothers brought *silver in their sacks' mouth* to purchase corn during a season of scarcity. Afterwards, when making himself known to his family, JOSEPH presented to his younger brother, BENJAMIN, three hundred pieces of silver. The author of the book of Job, who is certainly a very ancient writer, not only speaks of *the dust of gold*, but says, *Surely there is a vein for the silver, and a place for the gold where they find it*; so that he seems to have been well acquainted with the fact that silver was found in veins, and gold commonly in small particles. The vast amount of the precious metals accumulated by DAVID and SOLOMON has been mentioned in the article on GOLD, and in the first book of Kings it is stated that all the vessels of the house of the forest of Lebanon were of pure gold; *none were of silver, for that metal was nothing accounted of in the days of SOLOMON*, and, in short, *the king made silver to be as stones in Jerusalem*.

The accounts given by the profane writers of antiquity are equally surprising, and some of them altogether incredible. In POLYBIUS, for example, is found a description of Ecbatana, at a period subsequent to the capture of that place by ALEXANDER, in which it is stated that the beams, the roofs, and the pillars which supported the porticos and peristyles of the palace, were all covered with plates, some of silver and some of gold. The tiles, likewise, were all of silver. Though the place had been three times plundered before ANTIOCHUS arrived, there were still remaining in the temple of Ena some pillars cased with gold, and a large quantity of silver tiles, laid together in a heap. CRÆSUS, king of Lydia, who lived about five hundred and forty years before Christ, and whose wealth has become proverbial, is stated by HERODOTUS and DIODORUS to have made presents to the temple of Delphi amounting to four thousand talents of silver and two hundred and seventy talents of gold, or near three millions in value of British money.

The principal sources from which the ancients obtained their gold have been mentioned in the article

on that metal, and probably much of their silver was obtained from the same localities. PLINY speaks of a people named the Dardaneans, who inhabited a country the richest of all India in gold mines, and the Silians, he says, have the most abundant mines of silver. The chief sources of the wealth of the ancient kings of Egypt were the mines of the neighboring countries of Nubia and Ethiopia, which produced not only copper in abundance, but also gold and silver, before iron was known in Africa. According to XENOPHON, the Athenians worked the silver mines of their own country—Attica—from an unknown age, as well as the gold mines in their foreign possessions in Thrace, and in the island of Thasus. Epirus also had silver mines, which continued to be worked in the time of STRABO; but it appears probable that, for a long time, the only ore that was used was that found near the surface. The Colophonians were the most celebrated among the Greeks for their skill in smelting gold, but none of them were equally expert in smelting silver; for, according to STRABO, their successors were enabled to separate the silver from the residual earths with a profit, although even the latter were much inferior in skill to modern metallurgists.

But the country most productive of the precious metals, and especially of silver, in very remote ages, was the Spanish peninsula, which many authorities assume to have been the Tarshish of the sacred writings, to which a commercial expedition was sent by SOLOMON. It is certain that Spain was visited and colonized by the Phœnicians at a very early period, and that continual intercourse was maintained between the colonists and the mother country, as well as with the future descendants of the same race, the sons of Tyre and Sidon, who founded Carthage. The story of the discovery of the mineral wealth of the country, as related by Diodorus, resembles many of the fables which in ancient times were dignified with the name of history. He states that the Pyrenean mountains were covered with thick woods, which were set on fire either by the shepherds or by lightning, and continued burning so long that the heat melted the minerals, in consequence of which the silver, with which the soil abounded, ran down into the valleys like a stream of water! He adds, that as the inhabitants were unacquainted with its value, they readily exchanged it with some Phœnician traders, who accidentally visited their shores, for some trifling articles of ornament. The traders loaded their vessels with the precious metal till they could carry no more, and then cut their leaden anchors from the bows, and replaced them with others of silver. These statements are extravagant; but there is no doubt that in ancient times a vast amount of silver was successively extracted from Spain by the Phœnicians, the Carthaginians, and the Romans, and exported to all parts of the world in exchange for merchandise.

Gold, iron, and lead were procured in the South, and some tin in the North of Spain; but the gold was probably of small amount, and silver was the chief mineral wealth of the country. Of this mineral PLINY says it was found in all the Roman provinces, but the best in Spain, and that in a barren soil, even in the

mountains; and wherever one vein was discovered, another was found not far from it. He mentions, as a very singular fact, that the mines begun by HANNIBAL still existed in his time, and retained their original names. One, which was still called Bebulo, from the discoverer, had formerly supplied HANNIBAL with three hundred pounds weight of silver daily. This, he adds, was effected by means of passages under the mountain a mile and a half in length, in which the laborers, standing in water, worked night and day by lamp-light to draw off the water, which at length accumulated to such an extent as to form a large river. JACOB, in his *History of the Precious Metals*—an elaborate work, to which the Editor is chiefly indebted for the facts condensed into this historical notice—states that the situation of the mine mentioned by PLINY is at present well known to have been at Guadalcanal, in the modern province of Cordova, at the foot of the Sierra Morena; and, judging from what has been surveyed of it in more recent times, the water, which was imperfectly drained by the costly subterranean tunnel noticed by PLINY, has long since overflowed the whole interior of the mine; but whether it was exhausted of its treasure and abandoned on that account, or whether it was destroyed by the influx of the water, cannot now be ascertained. It is interesting to remark that HANNIBAL chiefly derived from the silver wealth of Spain the sinews of war, which enabled him to shake to its foundations the Roman empire; and, for many years, he greatly over-worked the mines of that country in his eagerness to accumulate and hoard immense treasures, with a view to the accomplishment of the one great object on which he had set his whole heart.

During several centuries of profound darkness which succeeded the overthrow of the Roman empire, mining operations appear to have been suspended throughout Europe, and the dates at which they were generally resumed are not precisely known. The chief sources of mineral wealth in the middle ages were the Austrian mines, or at least those which existed in countries that are now included within that empire; and, of these, it is considered probable that the mines of Chemnitz and Kremnitz in Hungary were those first worked. FERBER dates the opening of Chemnitz in 745, and that of Kremnitz in 770; but AGRICOLA, who states that they had previously been worked by the Romans, dates their reopening nearly a century earlier. The silver in these mines is chiefly found in lead, in a proportion varying from two to twenty ounces of silver in a hundred pounds of the baser metal. In Bohemia there are celebrated mines of silver at Joachimsthal, in the circle of Saatz, but at what period the workings in them commenced does not appear. In some of these mines the galleries have been carried to the extent of five thousand six hundred fathoms, and some of the shafts are three hundred and fifty fathoms in perpendicular depth. At Altenberg, also, the metals were found in beds of gneiss, in which were mingled felspar and granite; but the mines of Schellgadin are at present the most important. These were also originally worked by the Romans, and the earliest records of their resumption date back to 1378. In the

Tyrol, near Brixen, are silver mines, which, during the excitement in the sixteenth century occasioned by the discovery of the mineral treasures of America, obtained the name of El Dorado. In the year 1523 they produced three thousand eight hundred pounds of silver, but subsequently they decreased in value, and have long been discontinued.

The mines of Saxony, says JACOB, were first discovered in the tenth century, when the whole district in which they are situated was covered with wood, and without inhabitants. Some carriers from Halle, on their way to Bohemia, observing metallic substances in the tracks made by the wheels, took them up and sent them to Goslar to be examined, when they were found to consist of lead with a considerable quantity of silver. This led to the establishment of mining operations, which have continued from the year 1169 to the present day. For some years in the fourteenth century the mines of Schneeberg are said to have yielded so large a portion of silver, that the tithes on it amounted in thirty years to three hundred and twenty-four thousand quintals; but these latter mines have long been exhausted.

The mines in the Harz forest in Germany, which, at the time of this discovery, formed a portion of Saxony, are now partly in the dominion of Hanover, and partly in that of Brunswick. There are various conflicting opinions respecting the discovery of the mineral wealth of the Harz. The most probable accounts fix it in the tenth century, and the tradition is that a hunter of the name of Ramm, when engaged in the chase, had fastened his horse to a tree, when the animal, by pawing with his feet, scraped away the soil, and thereby discovered some minerals. Specimens of these were sent to the Emperor OTTO, who immediately despatched expert miners to examine the district. The result was that mines were established, which still continue to be worked, and the oldest is named Rammelsberg, from the discoverer. JACOB estimates the whole Harz, including the dominions of Hanover and Brunswick, with a small part belonging to Prussia, to have yielded, for some years prior to 1830, about sixty ounces of gold, and three hundred thousand ounces of silver annually.

From the times when the rich mines of Spain were last worked by the Romans, they seem to have been greatly neglected. CARDENNE, however, asserts that the mines of gold and silver which existed in that country were a great source of wealth to the Arabs. The mine of Zalamea, to the South of the river Guadiana in Andalusia, appears to have been worked in the middle ages. It is said to have contained silver without any mixture of lead, though near it was another mine yielding only lead; but the most important mines of Spain, and those which have attracted the greatest attention, from the earliest ages down to recent times, are the quicksilver mines at Almaden, and the silver mine at Guadalcanal. Of the latter Mr. BURN observes, that very minute and authentic records were preserved during the period it was worked in the sixteenth century, on account of the government. In these it is stated to have produced four hundred thousand two hundred and twenty-three

marcs of silver in the first few years after its discovery, and while worked by the state. After this period it passed into the hands of the Fucares, who are said to have obtained immense treasure from the mine previous to its being abandoned, and filling with water. It is only within the last twenty years, adds the same authority, that Spain has again become a silver-producing country, several very rich mines of that metal having been discovered since the recent revival of mining, which dates back only from 1825. In 1839 the celebrated mines of the Sierra Almagrera in the province of Almeria, were discovered, and they have ever since poured a large amount of silver annually into circulation. In 1843 another great discovery of silver was made—the mines of Hicndelencina in the province of Guadalajara, which have since been very productive; and, passing over recent and minor discoveries, Mr. BURR states that within the last few years the introduction of Mr. PATTISON's desilvering process—a process fully explained in the article LEAD—has been very general in the provinces of Murcia and Almeria. A large quantity of silver is thus annually obtained from the slightly argentiferous lead ores of the Sierra de Gador, and of Cartagena, not formerly extracted, but which now contributes to swell the production of this metal in Spain.

The silver mines of Norway and Sweden were long famous, but have latterly become less productive. The mine of Sahl, or Sala, is said to have been worked five hundred years ago. The silver mines of Kongsbø, in Norway were scarcely known before 1623. In some years between 1710 and 1767 they yielded a large profit, but in others they were attended with heavy loss, and have frequently been suspended for long periods.

Although in ancient times Britain was celebrated only for its tin, and yielded but small quantities of the precious metals, yet not only does proof exist that gold was found to some extent, but STRABO states that silver mines were worked in this island, and TACITUS represents AGRICOLA, in his oration before the battle of the Grampian mountains, as reminding his soldiers of the riches in gold and silver which were to reward their valor. It is probable that these riches existed only in the historian's imagination—so far at least as they were to be found in a form available to the metallurgical skill which then existed. In modern times silver has been found in the British islands only in small quantities, except in connection with lead; and before the introduction of Mr. PATTISON's process, the trouble of its separation from that metal more than counter-balanced the profit. There are records, however, of silver mines in Cardiganshire, and also in the county of Tipperary in Ireland, both of which are said to have been worked to some extent during the reign of ELIZABETH. It is stated also that Sir JOHN ERSKINE was a proprietor of silver mines at Alva, near Stirling, which ceased to be worked in 1729, having been carried on for six years previously, under the direction of one PECK, an Englishman; and in the reign of MARY STUART some silver mines were worked near Linlithgow. The produce must have been very trifling, and the profitable mining of either of the precious metals

was virtually a thing unknown in this country until the introduction of Mr. PATTISON's process rendered it advantageous to extract silver from lead; and as this metal is produced to a greater extent in Great Britain than in any other country in the world, the result is that, by virtue of the process above-mentioned, it is now actually entitled to no mean rank as a silver-producing country. The lead of some of the English mines, especially those of Cornwall, and also of the Isle of Man, contains considerable quantities of silver; and the reader will be surprised to learn that one of the highest authorities on this subject, Mr. ROBERT HUNT, has estimated that in 1852 the United Kingdom furnished no fewer than eight hundred thousand ounces of silver, worth, at five shillings an ounce, about two hundred thousand pounds, obtained from lead alone.

But the greatest impetus given to the supply of silver in what may be termed the modern era, arose from the discovery of America by COLUMBUS in 1492. It is true that up to the invasion of Mexico by CORTEZ, in 1519, gold alone had been found in America; or if any silver was procured, it seems to have been in small quantity: Thirty or forty years after that event, mines were in full work at Tasco, Zaltepique, and Pachuca, but the use of mercury was not yet understood. The smelting of the ore was performed in small portable furnaces, or cylindrical tubes of clay, very broad and pierced with a great number of holes. In these the Indians placed layers of silver ore, galena, and charcoal, and a draught was created by the current of air which passed through the holes. Twenty years after the conquest of Mexico by CORTEZ, PIZARRO achieved that of Peru, and numerous mines yielding both gold and silver were soon opened in that country, but none equal in importance to the celebrated mines of the Cerro de Potosi, which were discovered accidentally in 1545. According to HERERA, the discovery was made by an Indian hunter, DIEGO HUALCA, who, in pulling up a shrub, observed filaments of pure silver about the roots. On examination the mass was found to be enormous, and a very great part of the population was drawn to the spot and employed in extracting the metal. A city soon sprung up, though in a district of unusual sterility. The mountain was perforated on all sides, and the produce in a few of the first years exceeded anything that had been previously recorded in the mining history of the world.

The sensation created throughout Europe by the news of the discovery of the silver treasures of Potosi, can only be compared to the similar effect produced in recent times by the discovery of the auriferous deposits of California and Australia, which has been fully described in the article GOLD. The wealth of the new El Dorado was, however, grossly exaggerated. From reliable data it has been estimated, that between the year 1557, when the process of amalgamation was introduced, and the year 1578, the annual product of the Potosi mines did not exceed four hundred and forty thousand pounds sterling, which sinks into absolute insignificance compared with the vast amount of treasure now annually exported from California and Australia, without including the newly discovered and still comparatively unexplored deposits on the

banks of the Fraser River. On the whole, the greatest produce of gold and silver, even at that period, was from the Mexican mines, some of the richest of which were already in full activity, although the amount which they yielded was at that time much less than in the course of the two following centuries—the seventeenth and eighteenth—when quicksilver became more abundant, and was more extensively employed in the process of amalgamation. The chief increase of the precious metals between the years 1500 and 1600, was in silver from Mexico, where the production of Zacatecas, Guanajuato, and the other mining districts, had then greatly advanced. In the seventeenth century the silver mines of Yauricocha or Pasco, in the northern part of Peru, were first opened, and yielded a large amount of that metal. It is thus that though Potosi, which had at first produced the greatest quantity of silver, had declined, the product of the other parts of Peru so much increased as more than to compensate for that deficiency; and this increase, especially of silver, was greatly facilitated by the extension of the mines of mercury at Huancavelica.

The product of the precious metals from the American mines continued steadily to increase till 1809, when the convulsions commenced which terminated in the separation of the Spanish vice-royalties from the yoke of the mother country, and the erection of Mexico, Peru, and Chili into independent republics. During these troubles, which continued from 1809 to 1821, the produce of the mines greatly decreased, but has since been gradually augmenting.

The aggregate and relative amounts of silver obtained from different parts of the world, will be stated at the end of the article under the head of Statistics.

SOURCES.—As silver is of great use in the arts, not only for purposes of coinage, but also for services of plate for which it is peculiarly adapted, inasmuch as it is seldom attacked in the slightest degree by any of the substances used for food, so it occurs in great abundance in nature, and is largely disseminated both in the native state and alloyed with various other metals, occurring particularly in lead ores, as noticed under the article LEAD.

Native Silver is characterized by most of the properties of pure silver, but is always alloyed with a small quantity of other metals. It is generally dull at the surface, but exhibits, on being scratched, the pure white color characteristic of the metal. From its slight impurities, it is also less malleable and ductile than silver perfectly pure. It occurs sometimes crystallized in cubes and octahedrons; sometimes in thin leaves or in dendritical or arborescent shapes, resulting from minute crystals implanted upon each other; frequently also it is found in amorphous masses. It is met with chiefly in the primitive formations, as in granite and gneiss; more rarely in the argillaceous schists and grauwacke of the transition rocks, accompanied by quartz, carbonate and fluoate of lime, sulphate of barytes, carbonate of iron, galena, *et cetera*. The principal localities in which it occurs native are—Kongsberg in Norway; Schlangenberg in Siberia; Freiberg, Schneeberg and Johanngeorgenstadt in Saxony; Joachimsthal, Przibram, and Ratiboritz in Bohemia; Schemnitz in

Hungary; Kapnik and Felsobanya in Transylvania; Andreasberg in the Hartz; Allemont in France; and, lastly, Mexico and Peru in America. In some of these localities it has been found occasionally in considerable masses. Thus, at Kongsberg, pieces have been extracted weighing from fifty to six hundred pounds; in America, at the end of the last century, lumps of two hundred to eight hundred pounds were obtained; and on one occasion a block of solid silver was discovered in the mine of Johanngeorgenstadt, which is said to have weighed nine or ten thousand pounds.

SULPHIDE OF SILVER—*Glaserz* or *Silberglanz*, German—contains eighty-five to eighty-seven per cent of metallic silver. It is of a blackish dark-grey color, dull externally, but showing a metallic lustre when cut. It crystallizes in cubes or octahedrons, but is generally met with in the amorphous state. It is slightly malleable, almost as soft as lead, and is easily cut with a knife. It fuses readily in the flame of a blow-pipe, and even in a simple jet of gas, disengaging a slightly sulphurous odor, and ends by being reduced on the charcoal to metallic silver. It is met with in nature almost always combined with other sulphides, as those of copper and lead. This mineral is one of the richest and most abundant ores of silver; it forms a large proportion of that annually produced by the various foreign mines, as those of Saxony, Bohemia, and Hungary, and is particularly abundant in the mines of Guanajuato and Zacatecas in Mexico. Its composition, according to KLAPROTH, is—

	From Himmelfurst	From Joachimsthal
Silver,	86.50	86.39
Sulphur,	13.50	13.61
	100.00	100.00

RED SILVER.—*Rothgültigerz*, German.—There are three species of this mineral:—1. *The antimonial sulphide of silver*, or a double sulphide of silver and antimony—an ore of a dark-red or reddish-black color, very nearly opaque, has a metallic lustre, and usually crystallizes in hexahedral prisms. Its constituents are—silver, from 56 to 62; antimony, from 16 to 20; sulphur, 11 to 14; and oxygen from 8 to 10. It is met with in almost all silver mines, but principally at Andreasberg in the Hartz, Freiberg in Saxony, Kongsberg in Norway, Schemnitz and Kremnitz in Hungary. 2. *Praistite*, or the double sulphide of silver and arsenic, which is of a clear red color, transparent, with a brilliant lustre, and contains sixty-four per cent of metallic silver. 3. *Myargyrite*, which differs from the antimonial sulphide only in containing one-third of the proportion of sulphide of silver.

BRITTLE SULPHIDE OF SILVER—*Sprödglasserz*, German—presents two varieties essentially distinct—

1. *Polybasite*, a combination of sulphide of silver, sulphide of copper, and sulphide of antimony or arsenic; has a semi-metallic lustre and an iron-grey color; seen by transmitted light, in thin scales, it presents a blood-red color; it contains 60.5 to 72.25 per cent of silver, and is found chiefly in the Saxon mines, and also in Mexico and Peru. 2. *Brittle Sulphide of Silver*, properly so called—German, *Schwarzgültigerz*—which is a combination of sulphide of silver with the sulphide of anti-

mony or arsenic; lustre slightly metallic; color iron-grey, and black when reduced to powder; is found associated with the preceding, as also in Hungary, Transylvania, *et cetera*. According to the investigations of ROSE and KLAPROTH, its composition is as follows—

	From Freiberg By Klaproth.	From Schemnitz By Rose.
Silver,.....	68.50	68.34
Copper and Arsenic,.....	00.50	0.64
Iron,.....	5.00	0.00
Antimony,.....	10.00	14.60
Sulphur,.....	12.00	16.42
Loss,.....	6.00	—
	100.00	100.00

Grey argentiferous Copper—*weissgültigerz*, German—a combination of sulphides of silver, copper, lead, and antimony; has a semi-metallic lustre, and a color intermediate between that of lead and steel. That which is found in the mines of Freiberg contains thirty to thirty-two per cent. of silver. The *graugültigerz* is a variety of grey copper much poorer in silver than the preceding.

Plumbo-argentiferous sulphide of bismuth—*wismuth-bleierz*, German—is a brittle, leaden-grey mineral; it is a triple sulphide of bismuth, lead, and silver; contains fifteen per cent. of metallic silver. It is found at Schapbach in the Black Forest, but is a rare mineral.

Antimonial Silver—*speissglanz silber*, German—is a semi-metallic substance of a silver-white color, containing about seventy-seven parts of silver and twenty-three of antimony; it is found at Wolfach in the Black Forest, and in some of the Hartz mines, sometimes crystallized in rectangular prisms, but oftener in concrete masses.

Chloride of Silver.—*silberhornerz*, German, horn-silver—is semi-ductile and sufficiently soft to be cut with a knife; color, pearl-grey inclining to blue, and becoming brown in the air; has a vitreous lustre; is usually translucent; crystallizes in cubes. When pure it consists of silver 75.3, chlorine 24.7, and its composition is therefore represented by the formula Ag Cl .

This mineral, says PHILLIPS, which was formerly supposed to be of rare occurrence, constitutes one of the richest and most abundant ores of Chili, where it is frequently associated with native silver, apparently resulting from its decomposition. It also occurs in massive amorphous fragments in connection with sulphide of silver, but still more frequently in small cubical crystals disseminated in the ferruginous rock known in Chili and Peru under the names of *pacos* and *colorados*. Specimens of this mineral, although of comparatively rare occurrence in the European mines, have been obtained from Norway, Siberia, Saxony, the Hartz, and Cornwall.

Iodide of Silver is a rare mineral of a pale lemon-yellow color, with sometimes a tint of green. It was discovered by M. VAUQUELIN in the Mexican mines, but, from its rarity, is of no importance as an ore of silver. It is composed of silver 77.4, iodine 22.6.

Bromide of Silver was discovered by M. BERTHIER in the Mexican minerals, where it has since been found so abundantly in the district of Plataros, near Zacatecas, that the ores there raised have received the name of *platu verde*, from the green color which it imparts to

them. According to BERTHIER, it is composed of silver 57.70, bromine 12.50.

Native Amalgam, or *argental mercury*, has a very bright silver-white color, and is so soft as to be easily cut with a knife. It occurs both in distinct crystals and in irregular amorphous masses. It crystallizes in the regular octahedron or dodecahedron. This mineral is found in a great many different localities, but the finest specimens have been procured from Moschellandsberg in Bavaria. Its specific gravity is 14.1, and, according to KLAPROTH, it contains thirty-six per cent. of silver and sixty-four of mercury.

Another species of this substance, says PHILLIPS, forms one of the principal sources of silver in the rich mines of Arqueros, in the province of Coquimbo, Chili. From its malleability and general appearance this product was for a long time thought to be metallic silver. According to the analysis of Professor DOMEYKO, of the mining school of Coquimbo, this amalgam consists of silver 86.63, mercury 13.37, from which it appears to be composed of six equivalents of silver united to one of mercury, and its composition may therefore be represented by the formula Ag_6Hg .

Argentiferous Galena.—The sulphide of lead, or galena, is almost always associated with a small quantity of silver in the state of sulphide, and this is the source of the silver obtained in the British Islands. It is regarded as extremely rich when it contains 0.005 of silver, and in many cases it may be extracted with advantage when only a tenth part of that proportion is present.

In general, and whatever may be their nature, minerals are regarded as rich which contain 0.005 of metallic silver.

PURE SILVER.—The silver of commerce is never perfectly pure, being always mixed with a certain proportion of copper and traces of other metals. A small quantity may be obtained pure by dissolving a piece of money or of plate in nitric acid, and adding a solution of chloride of sodium; a double decomposition occurs; the silver is thrown down in the form of an insoluble chloride, while the copper and any other metals that may be present remain in solution. One hundred parts of this chloride are, when separated and dried, mixed with seventy parts of chalk and four or five of carbon, and this mixture is introduced into a crucible and raised to a white heat. Carbonic oxide is disengaged, and chloride of calcium and metallic silver remain in the crucible.

To obtain the silver in a state of great purity, the chloride obtained by the double decomposition in the first instance ought to be repeatedly washed by decantation with boiling water, to be certain of dissolving the other metallic chlorides. Instead of chalk, the operation succeeds perfectly by mixing equal parts of carbonate of potassa or soda with three or four per cent. of charcoal in powder. But as the mixture fuses, the disengagement of gas produces, in this case, a tumescence which may project the matter out of the crucible. For this reason GAY-LUSSAC preferred the use of carbonate of lime, with which the reaction may be effected without fusion, reserving the temperature capable of melting the mixture for the time when, the

reaction being finished, no more gas can be disengaged. When the contents subside, the crucible is filled up with more of the mixture; and when the reaction is finished, the temperature is raised to a white heat; the chloride of calcium and the silver are melted, and the latter forms, on cooling, a button at the bottom of the crucible. The chloride of calcium, which lies above it, always contains a certain quantity of chloride of silver; and to separate the silver from the chloride recourse is had to the humid process. The chloride is first purified by washing, and then subjected to the action of a little sulphuric acid, and a plate of zinc purified by distillation. The reduction is effected rapidly, and the silver forms a grey, spongy, mass, which often floats on the top, because it is penetrated by hydrogen gas proceeding from the decomposition of the water. By stirring with a glass rod, after withdrawing the zinc plate, the hydrogen is separated from the spongy mass, which then falls to the bottom. The liquid is then decanted off, and its place supplied by water and a little sulphuric acid. This new treatment is necessary, for the spongy substance is a combination of silver with zinc, and not pure silver. Accordingly bubbles of hydrogen gas, proceeding from the solution of the zinc, are soon found to be disengaged abundantly. When this ceases, the powder is washed by decantation with boiling distilled water till the liquid is no longer rendered turbid by chloride of barium. In this way the silver is obtained pure, in a state of minute division.

Chemical Properties.—At ordinary temperatures silver is not acted upon by oxygen, but it is tarnished if exposed to an atmosphere containing very minute portions of sulphide of hydrogen, which is always present, to a greater or less extent, in the air of chambers heated by coal fires. When melted, however, in open vessels, it possesses the remarkable property of absorbing about twenty-two times its own bulk of oxygen, which in solidifying it disengages, producing, probably, that kind of metallic vegetation which takes place on the surface of the silver button when suddenly cooled in the cupel. It is not known whether there is chemical combination or merely mechanical absorption in this case; but BARRUEL considers the latter hypothesis by no means probable. The effects of this singular phenomenon, which has been already alluded to in Vol. II., page 284, in connection with the refining of gold, are best shown when the mass of metal is considerable, as, for example, about fifty or sixty pounds. They were carefully studied by GAY-LUSSAC and LUCAS, and are altogether so remarkable that a somewhat more minute account of them may not be unacceptable to the reader. After maintaining about the quantity of metal above-mentioned for a long time in a state of fusion, it is left to cool spontaneously, and begins to solidify at the surface. This process commences towards the edges, and advances towards the centre. The crust thus formed soon cracks, and very fluid silver escapes through the fissures, spreading itself over the surface in a thin layer. This first stage of the phenomenon appears due, not to a disengagement of gas, but rather to the expansion which results from a commencement of crystallization. Soon afterwards, as

the cooling proceeds, the gas in escaping begins to raise the solidified crust at several points, and produces a singular formation of miniature volcanic craters, through which a current of oxygen is disengaged, while lavas of melted silver stream over their edges. In the middle of each little crater the liquid mass is seen boiling violently. In proportion as the disengagement of gas proceeds, the height of these craters increases, in consequence of the solidification of the metal which flows over their sides; the greater part of them get partially choked up, whilst the gas escapes with a constantly increasing force, dragging along with it drops of melted silver, which it projects to a distance, and producing at each eruption small explosions, which succeed each other at very short intervals. The cones of eruption may ultimately attain a height of one and a half to two inches, with a diameter at the base of two to three inches; and for a quantity of fifty pounds of silver, the total duration of the *rochage*, as the process is termed in France, varies from thirty to forty-five minutes.

This phenomenon does not occur when the silver is alloyed with a small proportion of copper, gold, or lead; even one per cent. of copper prevents the absorption of oxygen on which it depends. That this is the cause of the phenomenon may be demonstrated on a smaller scale by heating to a white red in a crucible a considerable quantity of silver, and projecting upon it a little nitrate of potassa, which, by its decomposition, produces an atmosphere of oxygen. The crucible is then to be covered, and the heat continued for some time, after which the lid is removed and the vessel plunged into a tub of water, placing over it an inverted bell-glass filled with the same liquid; the oxygen which is disengaged is collected in the bell-glass, and may be measured. This experiment, says BARRUEL, is not without danger, for the oxygen may be disengaged all of a sudden, and thus produce a violent explosion.

When silver is subjected to a very high temperature, either by means of a burning lens, the flame of the oxyhydrogen blowpipe, or a powerful voltaic battery, it rapidly volatilizes, and burns with a greenish flame. In a state of fusion it may be crystallized, and in this case it assumes the cubical form.

Silver does not absorb the oxygen of the air when it is fused with the alkalis, and for this reason silver crucibles are used in laboratories for making analyses of silicates by means of the caustic alkalies, which would attack platinum ones. Chlorine, bromine, and iodine combine very well with silver, and of these three bodies iodine is that which has the greatest affinity for it. Of the acids, it is acted on most powerfully by nitric acid, which dissolves it in the cold; concentrated sulphuric acid requires heat to dissolve it. Hydrochloric acid attacks it only with difficulty, by leaving it a long time to digest; however, if the metal is in a very divided state, and the liquid be heated to ebullition, the action even of this acid is pretty rapid.

Silver readily combines with sulphur, and hence the fact already stated—the facility with which it is tarnished by contact with air containing even a very small proportion of sulphide of hydrogen. In this case its discoloration arises from the formation of a brown film of sulphide of silver. To clean articles so tar-

nished, the simplest method is to plunge them for some time into a solution of manganate of potassa—*chameleon mineral*—which is obtained by heating to redness a mixture of equal parts of potassa and binocide of manganese. In this operation the manganate is decomposed, and reacts on the sulphur of the sulphide of silver, which it oxidises and then dissolves. Oxygenated water, if convenient, may also be employed for the same purpose.

METALLURGY OF SILVER.—With reference to their metallurgical treatment, the minerals of silver are divided into four classes:—

1. Argentine ores, properly so called, and worked for the silver alone;
2. Ores of lead and silver;
3. Ores of copper and silver;
4. Ores of lead, copper, and silver.

The separation of silver from its ores is effected either by the method of amalgamation, or by a series of successive smeltings, which concentrate the silver in a certain quantity of lead, and the silver is afterwards separated by cupellation. The first of these processes consists essentially in bringing the silver ores, which have been previously pulverized and subjected to a special preparation, into intimate contact with metallic mercury; the silver is dissolved in the mercury, and the amalgam, being separated from the other matters by washing, is subjected to distillation; a residue is thus obtained. The advantage which this process presents over all others, is its great simplicity; but as any associated metals which may be present, such as copper and lead, are thereby lost, this method is usually employed only for ores which contain an insignificant proportion of these or other foreign metals. In the other processes the product obtained by successive roastings and smeltings is a quantity of *argentiferous lead* or *copper*, from which the silver remains to be separated. In the case of lead it is separated, as already stated, by cupellation; for copper, the mass must first be submitted to eliquation—an operation which consists in melting or *sweating out* the silver from the copper, and then cupelling with lead.

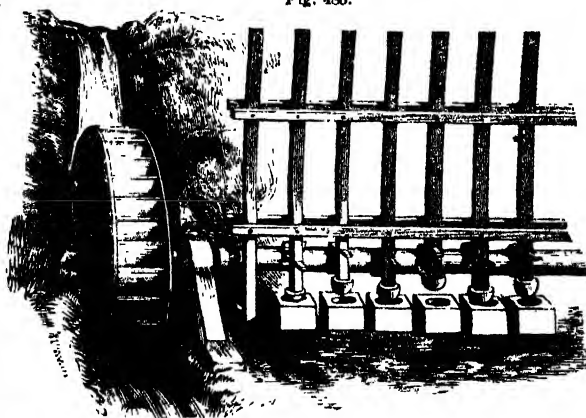
I. ORES WORKED FOR THE SILVER ALONE.—It has been stated that ores of this class, which do not contain an important proportion of other metals, are subjected to a process which consists essentially in forming an amalgam of the silver with mercury, and then subjecting the amalgam to distillation. This is the essential part of the process. Much of its success, however, depends on the manner in which it is conducted, and especially on certain preliminary operations which are required to bring the ore to that state of minute division in which it is most favourably circumstanced for causing the whole of the silver that is contained in it to combine with the mercury. There are two processes by amalgamation, the American or Mexican and the Saxon, which differ considerably from each other in this respect.

American process by amalgamation.—This method, invented in Mexico by BARTHOLOMEO DE MEDINA in

1557, is still practised in that country in all its primitive simplicity; and, perhaps, when the cheapness of labor, the poverty of the ores, the scarcity of fuel, and the deficiency even of water-power are considered, it could not be profitably superseded by any other. It will be found that its principal characteristics depend on these circumstances.

The ore, on being extracted from the mine, is placed in the hands of the *pepenadores*, men and women who break all the larger pieces with hammers, and after rejecting those in which their experience teaches them that no metallic particles are contained, and setting aside those which are very rich to be treated by the smelting process, they subject the rest to a process of crushing and pulverization, with a view to its direct treatment by amalgamation. The ores destined for this treatment are submitted in the first place to the action of the *ingenios* or stamping mills, which are either driven by mules, or, when water-power is at hand, by means of a small breast-wheel—Fig. 485. The long horizontal shaft fixed on the axis of the wheel is armed with five or six cams, placed at diffe-

Fig. 485.



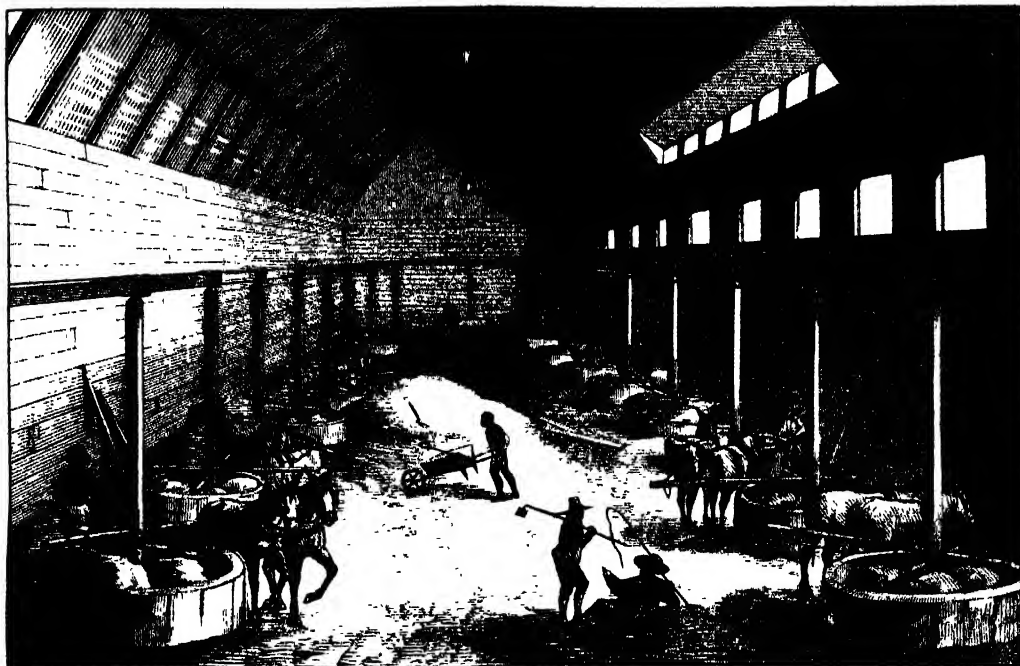
rent situations round the shaft, so as to act in succession on the projecting teeth of the upright pestles or stampers, each of which weighs two hundred pounds, and works in a corresponding oblong mortar of stone or wood. It is estimated that a battery of eight of these stampers, is capable of reducing to powder three thousand five hundred pounds of ore in twenty-four hours.

The powder thus obtained not being sufficiently fine for the purpose of amalgamation, it is transferred from the stamps or *morteros* to be reduced to an impalpable slime or mud in the crushing mills or *arrastres*, represented in Fig. 486, into each of which a little water is introduced. These mills are commonly worked by mules, which turn a vertical shaft armed with two cross-bars. The grinding stones, as well as the sides and bottom of the mill itself, are composed of granite, four blocks of which revolve in each crushing mill, one attached to each of the arms. They are usually placed in a covered shed or gallery, as shown in the figure, which represents the *arrastres* of the *hacienda* or metallurgic works of Salgado, near Guanajuato. These

contain thirty-six dry stampers, also worked by mules, and forty-two crushing mills in which water is used. Each of the latter reduces to a fine impalpable metal-

liferous mud six hundred pounds of powder in twenty-four hours. The mules are changed every six hours. This operation is considered of great importance, for

FIG. 488.



the subsequent amalgamation is so much the more complete, and the loss in mercury less considerable, in proportion as the ore is reduced to a more minute state of division.

The ore thus ground into a fine paste is termed

Fig. 487.



lama, and is conveyed into pits of three to six feet in depth, where it is allowed to dry in the sun till it acquires a certain consistence. It is then carried to the *patio* or amalgamation floor—Fig. 487—which is a flat space open to the sky, and surrounded by a stone wall. At Zacatecas the *patio* is rectangular, three hundred and twelve feet in length by two hundred and forty in breadth, and capable of containing twenty-four flat circular heaps of *lama*, each about fifty feet in

diameter and seven inches deep, arranged in four rows. These heaps are termed *tortas*. A small space is usually reserved at one corner for the purpose of performing assays on the ore, with the view of determining beforehand the proportion of mercury that may be necessary to incorporate with each heap.

At Zacatecas the *tortas* are formed in the following manner:—In the first instance a space of the requisite size is marked out and inclosed by a number of rough planks, which are propped in their places by large stones. About one hundred and fifty bushels of crude or impure sea-salt are then introduced into this inclosed space, and over this about six hundred metrical quintals of the *lama* or ore in a state of fine paste. The salt and *lama* are then well mixed by turning with shovels and treading with mules, after which the mixture is left at rest during the remainder of the day. On the morrow, after about an hour's further treading with mules, the *magistral*, or roasted and pulverized copper ore—a mineral containing ten per cent. sulphate of copper, and as much sulphate of iron—is added in greater or less quantity, according to the richness of the argentiferous ore and the season of the year; in summer, for example, and with the richer ores, about seven hundred and fifty pounds to the *torta*, and in winter only half that quantity; for it is stated as a singular fact that in summer the mixture cools and requires more warmth, while in winter it acquires of itself additional heat. The larger proportion is for minerals containing 0.0015 of metallic silver. When the operation proceeds too rapidly, arising from the presence of too much *magistral*, which would occasion

a greater loss in mercury, the remedy is to add a certain quantity of lime, which serves to cool the lama.

When the magistral has been introduced, the treading out is continued for five or six hours by means of six mules. When the whole has been well mixed, the process of amalgamation is commenced by adding a certain quantity of quicksilver, which is sprinkled over the heap by straining it through a bag of coarse cloth. The treading by mules is then continued, and the whole is turned over for some hours with wooden shovels. This operation is repeated for several days, until the amalgamator ascertains by examination that all of the mercury is taken up. He then adds a second and sometimes a third charge, repeating on each occasion the same treatment. When the last charge has been added, the mixture is again thoroughly trodden, and the mass is then removed by the laborers on handbarrows to the *lavaderos*, where the amalgam is separated from the earthy matters by washing.

To judge of the progress of the amalgamation from time to time, the amalgamator uses a small black earthenware basin, flat and round, or somewhat similar in form to that represented in Vol. II., Fig. 221, page 272. In this dish he puts a little of the lama or paste which is under the process of amalgamation, and holding the dish inclined and half-immersed in the water, he gives it a rotatory movement in a plane perpendicular to its axis, so that there is formed in the submerged part of the basin a circular current of water which retains the sand in the centre, while the heavy or metallic grains arrange themselves around the circumference according to their specific gravities, and there the amalgam is observed in small spangles. Usually eight parts of mercury are added for one part by weight of silver contained in the ore. Thus, at Zaccatecas, for an ore which is presumed to contain 0.001625 of silver—and this is the average proportion—there is added to the torta, which is estimated to contain about two hundred pounds of silver, on the first occasion nine hundred pounds of mercury; on the second, three hundred pounds; and on the third and last, four hundred and twenty pounds, making a total of one thousand six hundred and twenty pounds of quicksilver. The entire duration of the amalgamation is twelve to fifteen days in summer, and twenty to twenty-five in winter. This is less than a third of the time required at some other Mexican mines, which evidently arises from the small elevation given to the tortas, and the consequent exposure of a large surface to the action of the solar rays.

The next operation is the washing of the amalgamated ore, for the purpose of removing the earthy matters, and of thereby obtaining the amalgam or mixture of silver and mercury in a separate form. This operation is performed in *lavaderos*, or washing vats, which are circular in form, and solidly built in masonry, each about eight feet deep and nine in diameter. A horizontal toothed wheel, mounted on a shaft worked by mules, communicates, through the intervention of another toothed wheel, a movement of rotation to a vertical shaft placed in the middle of the vat, and armed at its lower part with four agitators consisting of cross

beams, from which rise long wooden teeth to the height of five feet. A small stream of water continually flows into the vats from a tank on a higher level. Under the action of the agitators the lighter earthy matter is kept afloat, while the heavier amalgam sinks to the bottom, and from time to time the former is allowed to flow out into a second similar apparatus, where it is subjected to a second washing, and then allowed to run away. An entire torta of amalgamated ore may thus be passed through one vat in twelve hours.

The liquid amalgam obtained in this manner is then strained through a leathern bag, the bottom of which is formed of strong canvass or thick flannel. The uncombined mercury is thus squeezed out, carrying along with it a small quantity of silver, which is not lost, as the same mercury is employed in the next amalgamating operation, while there remains in the bag a mass of semi-solid amalgam, which is submitted to distillation to obtain the silver. For this purpose it is moulded into wedge-shaped masses, each about thirty pounds in weight, which are arranged in a circle in what is called the *burning house*, to the number of eleven, on a solid plate of cast-iron having a hole in its centre. Over this row of wedges several others are built, and the whole pile is covered with a large iron bell called a *capellina*, which is lowered down upon it by means of pulleys, and carefully luted at the bottom to the iron plate with a mixture of ashes, crude salt, and lama. A loose wall of fire-bricks is then built round the capellina, leaving an interval about a foot in width, which is kept filled with burning charcoal all night; and after the heat has been applied about twenty hours the bricks and ashes are removed and the capellina hoisted up. The silver is then found in a solid mass, the mercury having passed off in vapor through a pipe fixed to the opening or hole in the ground plate, by which it is conveyed into a cistern filled with water, and there almost all condensed. The silver, which remains on the plate in solid pieces, is weighed, and is then usually remelted in reverberatory furnaces, and cast into ingots or bars, each about eighty or ninety pounds in weight. Latterly, at some establishments cylindrical retorts of cast-iron have been introduced for distilling the amalgam. The loss in mercury is usually about one and a half per cent. of the weight of silver obtained.

The rationale of the process of amalgamation, as above described, may be explained as follows:—In America the silver exists in the ores, partly in the native state, partly as a chloride, and partly as a simple or multiple sulphide. The copper pyrites which is added reacts on the chloride of sodium employed, producing sulphate of soda and bichloride of copper; the latter acts as an energetic chloridizing agent on the sulphide of silver in the ore, which it changes into chloride of silver, passing at the same time itself into the state of protochloride. The chloride of silver is in its turn reduced by a part of the mercury added, forming with that part protochloride of mercury, and with the other an amalgam of silver. It is the protochloride of mercury so formed that is carried away by the waters in the process of washing, and constitutes almost the whole of the loss in mercury. The

chloride employed serves not only to transform the sulphate of copper into deutoclhoride, but likewise to dissolve the chloride of silver, and thus to facilitate considerably its reduction by the mercury.

On an average the American ores are very poor, and do not contain more than 0·00150 to 0·00160 of silver. It is their immense quantity, and not their superior richness, that explains the large production of the silver mines of America. The most celebrated are those of Pasco, Cerro de Bambon, Chota, and Huantajaya in Peru; Zaccotecas, Guanaxuato, Valenciana, and Veta-grande in Mexico. Pasco produces annually one hundred thousand to one hundred and fifty thousand pounds of silver; Huantajaya fifty thousand pounds; Zaccotecas three hundred thousand pounds; Guanaxuato two hundred thousand pounds; Valenciana one hundred and fifty thousand pounds. It is estimated that five-sevenths of the silver produced in America is obtained by amalgamation, and only two-sevenths by smelting the ores.

Saxon Process by Amalgamation.—It was only at the end of the last century that the method of treating silver ores by amalgamation was introduced into Europe. Here the circumstances are different to those in Mexico and Peru; fuel is cheaper, mechanical moving power is abundant; manual labor is more expensive; it is therefore important to replace the latter as far as possible by the former two, and this principle will explain the chief points in which the European process differs from the American. These points of difference will appear from the following account of the method by amalgamation, which is practised at the Halsbrücke works, near Freiberg, in Saxony, the most complete establishment of the kind in Europe.

In these works no ores which contain more than seven per cent. of lead, or ore of copper, are submitted to amalgamation, because beyond that point the lead entering into the amalgam would render it very impure, while making the operation itself more difficult, and the copper would be entirely lost. The most usual constituents of the ores are sulphur, silver, antimonial silver, bismuth, sulphides of arsenic, of copper, iron, lead, zinc, *et cetera*, with several earthy minerals. Ores of different qualities are sorted together in such a way that the mixture may contain an average of about four ounces of silver per one hundred pounds of ore. It is necessary, also, that they shall contain a certain proportion of sulphur, to decompose sufficient chloride of sodium in the roasting to cause as much chlorine to be disengaged as shall convert the whole of the silver into a chloride. Accordingly, ores poor in sulphur are mixed with those that are richer, and generally about thirty per cent. of iron pyrites is added. When the whole has been well pulverized in a stamping mill, about one-tenth of its weight of salt is added, and the mixture is then roasted in a reverberatory furnace, the floor of which is elliptical, and is about six feet in length by eight in breadth; the height of the vault in the centre is about eighteen inches. The furnace is charged with three and a half to four hundredweights of the prepared ground ore, which is first dried at a low heat with incessant turning over; the fire is then gradually raised. At first vapor of water is disengaged, then

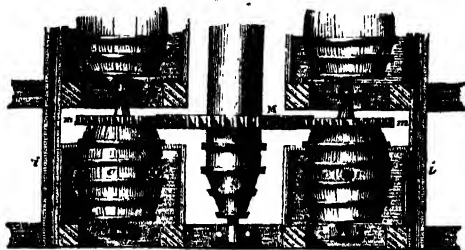
dense white fumes of arsenious acid and oxide of antimony, which deposit themselves in the condensing chambers above; after this the ignition of the iron pyrites becomes obvious by the appearance of a bluish flame and a strong odor of sulphurous acid. When this smell has passed away the chlorination is commenced by raising the temperature to a bright red, and maintaining it at that point till no more gas is disengaged; this requires about three-quarters of an hour, so that a charge is passed through the furnace every four hours. During the first part of the operation, or the roasting properly so called, the arsenic and antimony are separated, and the sulphides of iron and copper are converted into a basic sulphate of sesquioxide of iron and subsulphate of copper. These sulphates, in the second part of the process, or the chlorination, react in their turn on the chloride of sodium, producing sulphate of soda, protochlorides of iron and copper, and chlorine, which combines in the nascent state with the silver contained in the ore, thereby converting it into a chloride. Here it is the chloride of iron which principally acts as the chloridizing agent, whereas in the American process it is the chloride of copper. At the Halsbrücke works there are fourteen roasting furnaces, in each of which about five tons of ore are operated upon weekly; and the condensing chambers or soot vaults yield in the aggregate, during the same time, from four to five tons of ore-dust, containing about sixteen pounds, or 0·00125 to 0·00150 of silver. This dust is treated separately in the same manner as the crude or unroasted ore. The fuel of the first fire is pit-coal; of the finishing one fir-wood. Of the former one hundred and fifteen cubic feet, and of the latter two hundred and ninety, are upon an average consumed for every five tons of ore. The service of a roasting furnace requires two workmen per twenty-four hours of work.

The roasted ore is thrown on a grating inclined at an angle of 45°, and having sixteen apertures to the square inch. That which passes through falls on a sieve or riddle about eight feet long by eighteen inches in width; it is inclined at an angle of 6°, and, in the upper part, has eighty apertures to the square inch, but only fifty in the lower. Three degrees of fineness are thus obtained—the *coarse*, which remains on the grating and the riddle; the *fine*, which passes through the upper part of the riddle; and the *middling*, which passes to the lower part. On the average the proportions obtained are twenty-nine parts of fine, one of middling, and one and a half of coarse or large grains. The latter is broken with a hand-hammer; it is then crushed, along with the middling size, under granite millstones, and afterwards subjected to a second roasting with two per cent. of chloride of sodium; but in this case the operation lasts only two hours instead of four as formerly. The fine is ground in a dry state between granite millstones. The top stones or runners make one hundred and twenty to one hundred and forty turns per minute; they are radiated like those of meal mills; the grooves have a depth of about one-fifth of an inch, and require to be dressed or renewed every three or four days. When they are first put up they are about two and a half feet in diameter, with a thick-

noss of about twenty inches; and when this thickness is reduced one-half, they are used for the lower or bed stones. It is estimated that from two to three horsepower is required for each mill. There are in all ten pair of stones, and each of them grinds per hour from one hundred to one hundred and fifty pounds of roasted ore, besides which there remains on the bolter twelve to fifteen per cent. of coarse material, which must be passed a second time between the stones. The service of two pair of stones requires two workmen per twenty-four hours of work.

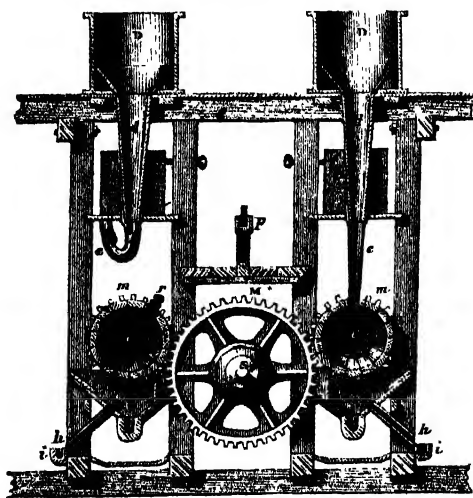
The amalgamation is performed in casks firmly hooped with iron, and each about two feet ten inches

Fig. 488.



long by two feet eight inches in internal diameter. There are twenty of them, arranged in four rows, and turning on horizontal axes. Figs. 488 and 489 will give an idea of this arrangement. Attached to the end of each cask, *c, c*, is a toothed wheel, *m m*, which engages another toothed wheel, *M*, mounted on a shaft,

Fig. 489.



s, which is driven by water-power. Each of the casks has an opening, *r r*, about four inches in diameter, and securely closed by an iron or wooden screw stopple during the amalgamation. The roasted ore is charged into hoppers, *D, D*, which are prolonged downwards by conical tubes, *d, d*, and leather hose, *e e*. The latter are introduced, during the charging of the casks, into the openings, *r r*, and then turned upward as one of them is shown in the figure. Above each cask is a vessel, *E*, for containing the exact amount of water

required for each charge, and these are also fitted with flexible tubes and stopcocks for allowing the water to pass as required. The bearings of the wheels, *m m*, mounted at one end of each of the barrels, and through which they receive their movement from the wheel, *M*, are supported on slides which move to and fro upon the bars, *f*, and the wheels can therefore be disengaged at pleasure. The charge is commenced by introducing into the barrels the water from the vessels, *E*, each of which contains thirty-three gallons, and the whole of this is transferred into the barrels; the roasted ore, to the amount of ten hundred-weights for each, is then introduced, and lastly there is added from eighty to one hundred pounds of iron in pieces about one and a half inch square by three-eighths thick. The stopples are then screwed in, and the casks are thrown into gear, and made to revolve slowly for about an hour and a half at the rate of fourteen to fifteen turns in the minute. During this stage, the chloride of silver dissolved in the alkaline chloride is decomposed by the fragments of iron, producing chloride of iron and metallic silver. It is very important that the roasting should have been carried far enough to decompose all the chloride of copper; for if not so, the latter would be equally reduced by the iron to the metallic state, and would subsequently pass into the amalgam, rendering it very impure. At the end of an hour and a half the barrels are stopped, and five hundred and fifty pounds of mercury introduced into each, by means of pipes connected with the tube *g*, which communicates with a large graduated iron reservoir. The barrels are then put in motion again, with a speed of twenty to twenty-two revolutions per minute, and this is continued for nineteen hours without intermission, except for a short period at the end of every four hours to examine whether the paste has the proper consistence, and to judge of the progress of the operation. The reaction is facilitated by the elevation of temperature which is observable in the contents of the barrels, and which is greater in proportion as the velocity of rotation is more considerable. The higher the temperature the more completely will the residues be exhausted, but the greater will be the loss, in the subsequent washings, of very minutely-divided mercury, which it will then be impossible to recover. There is therefore a proper medium, which has been determined by experience to correspond to about 90°.

The amalgamation being now considered as terminated, the barrels are nearly filled with water, and are made to revolve during two hours with a speed of eight or nine turns per minute, to collect the amalgam. The motion is then stopped, and the process of discharging them is proceeded with. For this purpose the conical bungs, by which they were hermetically sealed during the amalgamation, are removed, and a leathern tube fitted with an iron stopcock is inserted into each aperture; the barrels are then reversed, so that the apertures are turned downward, and the amalgam is made to fall along the sluice, *h*, into the gutter, *i*, which conducts it to a general reservoir. The barrels are then turned up to adjust to them hollow stoppers fitted with wire-grating; and in reversing them again the slimy residue falls into the canal, *o*, which

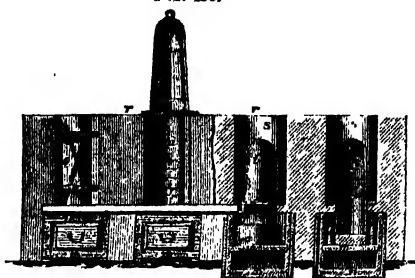
conducts them to the washing vats, while the pieces of iron retained by the grating remain in the barrels. Altogether each operation lasts twenty-four hours. About two pounds of iron are consumed in each barrel at one operation, and about thirty pounds are added every fifteen days.

The amalgam obtained is strained by hand labor through a flannel bag of a conical form; the mercury which passes through contains at the utmost 0·00004 of silver, and is passed back into the amalgamation barrels. The solid amalgam, which remains in the bag, contains, according to KERSTEN'S analysis:—

Mercury, ..	84·20
Silver,	11·00
Copper,	3·50
Antimony, zinc, and lead, ..	1·00
Sulphur,	traces.
Loss,	0·30
	100 00

Distilling the Amalgam.—The mercury is separated from the silver by distillation. For this purpose the amalgam is placed in flat iron dishes, under a bell-apparatus. Fig. 490 represents the four bells employed at the Halsbrücké establishment; *m, m, m, m* are wooden drawers, sliding in grooves upon the bases *q q*; and each of which contains an open box or basin, *o o*, of cast-iron. In these basins are placed vertical iron rods, *a a*, resembling candelabra, resting upon three

Fig. 490.



feet, and each supporting five flat iron dishes, formed with holes in the centre, whereby they are fitted upon the iron rods, three inches apart, each plate being successively larger than the one above it. About sixty pounds of amalgam are put into each dish, and the whole is covered with a cast-iron bell, *b b*, which is raised and lowered by means of pulleys. When the bells have been let down into their place, the aperture through which they descend is covered with an iron plate, *r*, and the open space, *s s*, which forms the stove, is closed in front with a door, *c*, the edges of which are carefully luted. The boxes, *m*, and basins, *o*, are filled with water, which must be continually renewed through pipes in the sides of the boxes, so that the iron basins may always be kept partially immersed, and as cool as possible. The fuel is then placed in the vacant spaces, *s s*, round the upper part of the bells; and the doors, *c*, being closed and luted, the fire is fed gradually, first with turf and then with charcoal, in such way that it does not attain its maximum heat until about eight hours have elapsed, after which the fire is allowed to decline gradually. The

management of the fire is a point of the greatest importance, and requires the most careful attention, for if the temperature be not raised very cautiously, there is much risk of the bell breaking, and also of a part of the silver being carried over mechanically by the mercury in volatilizing; on the other hand, if the temperature be not sufficiently elevated, there will remain in the silver a greater or less amount of the mercury, which will be completely lost in the refining.

Each distilling operation lasts twelve hours, and the product is about forty-five pounds of plate or *teller* silver from each bell. The teller silver contains only about seventy-five per cent. of fine silver, the remainder being chiefly copper; it is melted in an open iron crucible, and cast into ingots—a process by which some of the impurities are removed, and the ingots contain about eighty per cent. of fine silver.

The earthy residuum of the twenty barrels in which the amalgamation was performed is run into five circular tanks, each about five feet in depth, with a diameter of five feet at the top and three at the bottom; these are filled up with water, and in the side of each there are four orifices, arranged one over the other, at a distance of about five inches from each other. In the middle of each tank is a vertical axis, carrying horizontal arms, which are made to revolve during twenty to twenty-two hours at the rate of twelve to fourteen turns per minute; and while this agitating process is going on, the supernatant liquid, containing the lighter earthy impurities, is allowed to flow out, twice by the highest orifice, twice by the second, and once by the third or lowest, taking care to fill up the tanks with water after each partial discharge. The amalgam itself is drawn out by the lowest orifice only once a-week; it is very impure, and after being fused yields an alloy which contains only twenty-five to sixty-five per cent of fine silver. This product might be refined by fusing it with a little saltpetre and borax, but it is sent by preference to the Mint, where it is alloyed with the fine silver which is obtained from the cupellation of lead. The amount of the residues, which are finally rejected as useless, rises to eighty per cent. of the weight of the crude ore, and their contents in fine silver varies from 0·00008 to 0·00016. The waters which proceed from the washing of the amalgamation barrels are purified by deposition, and then concentrated and crystallized in leaden pans; the product is a quantity of impure sulphate of soda, which is februated by a second crystallization. The mother-water, or that portion of the liquid which refuses to crystallize, is concentrated by milk of lime; and the product thus obtained, which is termed in German *dünge salz*, is employed in the country with much advantage as a manure; it is composed, according to M. LAMPADIUS, of—

Hydrated gypsum,	68·7
Chloride of sodium,	7·4
Carbonate of potassa,	5·3
Hydrates of manganese and iron, ..	12·9
Clay, sand, and loss,	5·7
	100·0

The total loss in silver varies from five to nine per cent. of the quantity contained in the ore; the loss in

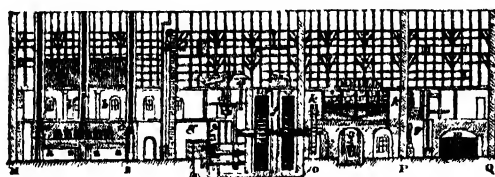
mercury amounts to twenty-five per cent. of the silver obtained, and, from an average of twenty years, it consists of—

Loss in mercury, which remains in the earthy residues of the amalgamation,	21.78
Loss in the distillation of the amalgam,	2.77
Loss proceeding from the cracking or breaking of the balls,	0.45
	<hr/> 25.00

This small consumption of mercury compared with that of the American process arises from the fact that in the latter the chloride of silver is reduced by the mercury, and the chloride of mercury thus formed passes wholly into the residues, whereas in the Saxon process this reduction is effected by the iron.

Fig. 491 presents a complete view of the amalgamation works at Halsbrücke, shown in longitudinal section; the portion on the left side, indicated by the letters *M N*, is devoted to the roasting and chloridation of the ores; the part embraced between *N* and *O* to the pulverization and sifting of the roasted ore; the third part, *O P*, to the amalgamation, properly so called, and the washing of the residues; and, lastly, the portion *P Q* to the distillation of the amalgam. In these four great divisions the following details will be distinguished:—
1. in division *M N*, *a a* denotes the salt stores; *b b* apartments for mixing the materials; *c c* roasting-furnaces, the flame of which, after passing over the hearths, 2, 3, enters the condensing chambers, 4, 5, and escapes by the chimney, *e*. 2. In compartment *N O*, *g* denotes the grinding mills; *d* the sifting machinery; *f* water-wheels which drive the grinding mills and amalgamation barrels. 3. In division *O P*, *k k* are the amalgamation barrels; *l*, tank for washing

FIG. 491.



the residues. 4. In compartment *P Q*, *m* denotes the furnaces for distilling the amalgam; *q*, store-chamber.

Thus, as the late Dr. URE has observed, from one extremity of the building to the other, the workshops follow in the order of the processes; and the whole, over a length of one hundred and eighty feet, seems to be a natural laboratory, through which the materials pass, as it were, of themselves, from their crude to their refined condition.

II. ORES CONTAINING LEAD AND SILVER.—The treatment of argentiferous lead ores, with a view to the separation of the silver, has been fully described in the article LEAD. It consists in simple cupellation, if the ores are sufficiently rich in silver to warrant the immediate application of that process; and the furnaces used for that purpose, both at Alston Moor in England and at Clausthal in the Hartz, are illustrated in Vol. II., pages 471, 472, where the whole operation is described in sufficient detail. The form of cupel used in England

is exhibited at page 284. The refinery furnace of the works at Friedrichshütte, near Tarnowitz, in Upper

Fig. 492.

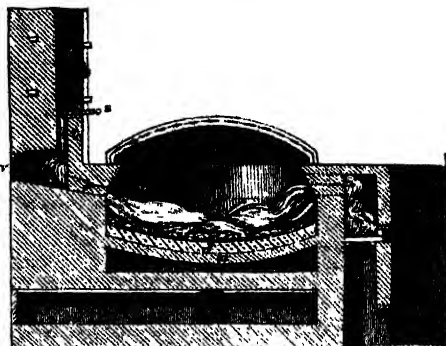
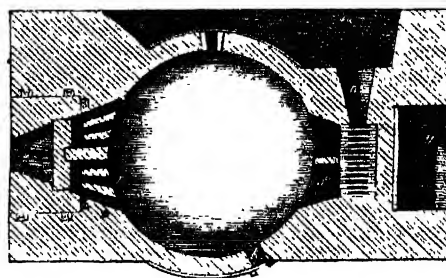


Fig. 493.



Silesia, is shown in section and plan in Figs. 492 and 493; *m* is a foundation of slag or cinders; *n*, a bed of fire-bricks, on which the cupel rests; *d*, the cupel, formed of a mixture of seven parts by weight of marly calcareous dolomite, and one of fire-clay—it is nine feet in diameter, and has a dip of fifteen inches in the middle; *g* is the grate of the furnace; *f*, the fire-bridge; *c*, the dome, or cap, made of iron-plate strengthened with bars, and lined with fire-lute to protect the metal from burning; *h*, the door of the fire-place; *i*, the ash-pit; *l*, the tap-hole; *pp*, flues, divided by partitions, which conduct the flame into the chimney, *tt*; *s*, a valve, or damper, for regulating the draught; *vv*, back valve for admitting air to cool the furnace and brushes to clean the flues, *pp*; *e*, tuyere of copper, which, by means of an iron wedge, may be sloped more or less towards the hearth; *w*, a round piece of iron hung before the eye of the tuyere to break and spread the blast; *k*, the outlet for the litharge. The charge is composed of seventy to eighty metrical quintals of lead. The fusion and removing of the abstrichs occupies six hours, and the formation of the litharges twenty-four to thirty hours—in all thirty to thirty-six hours.

Very poor leads cannot be directly cupelled with profit, because the value of the silver obtained does not defray the expense of the operation. In that case recourse is had to PATTISON'S process, which has also been fully described in the article LEAD, Vol. II., page 473; and after the lead has been enriched by successive crystallizations, it is then fit to be cupelled.

The following table exhibits the effect of PATTISON'S process on one thousand parts of workable lead containing different proportions of silver:—

Workable lead submitted to one crystallization.		Rich lead		Lead middling rich, to be recrystallized with the workable lead.	Poor lead		Proportion between the content in silver of the rich lead and that of the poor lead.
Weight.	Content in silver.	Weight	Content in silver.	Weight	Weight	Content in silver.	
1000	0.001806	136	0.003800	125	739	0.001200	3.17
1000	0.001230	136	0.003203	125	739	0.000862	3.70
1000	0.000862	162	0.002150	125	713	0.000568	3.78
1000	0.000598	169	0.001606	125	706	0.000357	4.49
1000	0.000568	169	0.001454	125	695	0.000341	4.26
1000	0.000341	234	0.000814	125	641	0.000170	4.80
1000	0.000234	250	0.000598	125	625	0.000088	6.79
1000	0.000088	259	0.000218	125	616	0.000033	6.61
1000	0.000030	100	0.000130	125	650	0.000020	6.50

It will be seen that the concentration of the silver by this process is all the more complete, in proportion as the lead subjected to the operation is poorer in that precious metal; hence, it is particularly applicable to the leads of England and Spain, but not to rich leads. Neither can it be applied with advantage to leads which are both poor and impure, because by cupellation the advantage is gained of separating the impurities in the abstrichs, so that litharges are obtained which are commercially valuable in themselves, or which, if subjected to reduction, yield a lead of superior quality.

The silver obtained from the cupelling furnace represented in Figs. 492 and 493, as well as the rich lead concentrated by PATTISON'S process, still requires further purification, and for this purpose it is subjected in both cases to cupellation on a small scale, with a cupel or test made of bone-ash. Figs. 494 and 495

Fig. 494.

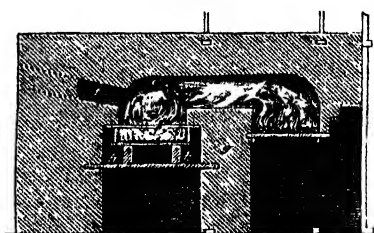
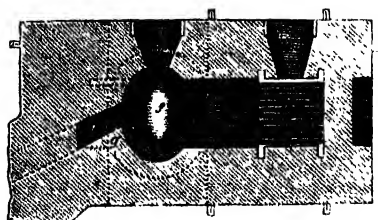


Fig. 495.



represent the refining furnace employed for this purpose at Friedrichshütte; *c* is the fire-door; *d* the grate; *e*, door for charging the rich lead into the cupel; *f*, elliptical cupel of bone-ash, the longer axis of which is about sixteen inches, and the smaller axis ten inches; this cupel is movable, and rests upon two iron bars, *g g*, over which are tiles, *h h*, for adjusting the surface

of the cupel at any desired level; *i*, flue leading to a chimney about eighteen feet in height. About one hundred and ten to one hundred and thirty pounds of rich lead or impure silver constitute one charge of the cupel; and the silver obtained from a previous cupellation on the large scale, yields about ninety-four per cent. of fine silver.

III. ORES OF COPPER AND SILVER.—In smelting argentiferous copper ores, the principal object in view is to obtain the baser metal in that state in which it is termed *black copper*; and when this metal contains not less than 0.003 of silver it is deemed sufficiently rich to be submitted to the process of liquation or sweating. This process has been briefly described in the article COPPER, Vol. I., pages 522 and 523; but some additional details will now be necessary. In the first place, the black copper is fused with a certain quantity of poor lead, and the alloy so formed is cast into cakes or discs; these are then submitted to a carefully graduated heat, which causes the lead to melt or sweat out, carrying along with it the greater portion of the silver, which has a stronger affinity for that metal than for the copper. This is the process termed liquation or eliquation. It has been found by experience that, with a view to diminish as much as possible the loss in copper and in lead, the most suitable proportion between the quantities of lead and copper in the prepared discs, is that of eleven parts of the former metal to three of the latter; and that, to extract the silver sufficiently, it is necessary to employ at least four hundred and eighty parts of lead for one part of silver contained in the black copper.

When the black copper is only slightly argentiferous, the poor lead, which has served for a first liquation, is not sufficiently rich to bear advantageously the expenses of cupellation; in that case it is used a second time for extracting the silver from a fresh quantity of black copper. By this means the content of silver in the alloy is nearly doubled, and then it is suitable for being submitted to cupellation.

Lastly, when the black copper is very rich, the process is commenced by subjecting it to a first liquation with workable lead, the products of which are a rich lead for cupelling, and a middling rich black copper; the latter is then submitted to a second liquation with poor lead, which yields cupreous residues very poor in silver, to be treated for rosette copper, and moderately

rich workable lead, which is passed back into the rich liquation process.

The content in silver of the black argentiferous copper of Mansfeld, which are treated at the liquation works of Hettstœdt, where both the lead and fuel are very high in price, averages 0·00520. The fusing and casting of the liquation discs is performed in a cupola furnace. Each campaign lasts thirty hours, during which time two hundred discs are cast, each weighing about three hundred and eighty pounds, and measuring about two feet in diameter by three inches in thickness. For one thousand pounds of black copper, the proportion of poor lead added is four thousand four hundred pounds. The liquation furnace, with the discs arranged in their place, is represented in Figs. 333 and 334, Vol. I., at the pages above referred to. When the lead, carrying most of the silver along with it, has been melted out, the deformed discs which remain are termed *carcas*. When the heat has been well regulated, all the lead which separates by liquation contains a uniform admixture of copper to the amount of between two and three per cent.

The *carcas*—German, *kienstœcke*—still contain twenty-five per cent. of lead, and, to free them from this, they are subjected to a new liquation, which is termed in French, *ressuage*; German, *darren*. For this purpose the *carcas* are accumulated to the extent of fifteen to twenty thousand pounds weight, in a vaulted chamber, on a series of low parallel walls, between which a wood fire is kept up. In the walls of the chamber are a number of draught holes communicating with a chimney. In front this oven is closed by an iron door lined with clay, but leaving an opening at the bottom for the purpose of introducing the fuel and allowing air to enter. A red heat is kept up during fourteen to fifteen hours; the lead which was still retained by the *carcas* soon begins to run, and becomes in great part oxidised. It falls into the galleries in the middle of the fuel, which have a gentle slope, so that both the lead and its oxide, more or less charged with copper, flow into a basin of water which is placed on the floor of a chamber in front of the oven. The fire is allowed to go out when the scoriæ assume a strong red tinge, which denotes the presence of copper. The residues, which are termed *torrefied carcass*, are then withdrawn, while still at a red heat, and thrown into water to separate the scaly crust of oxide with which they are covered, and which is afterwards separated more completely by means of a pointed hammer. As a general rule, one hundred pounds of *carcas* yield sixty to eighty pounds of torrefied *carcas*, and twenty-five to forty of scoriæ and oxidised debris.

The torrefied *carcas* are refined for rosette copper; they still contain ten per cent. of lead, and yield seventy to seventy-five per cent. of rosette copper.

The scoriæ and refuse of all the preceding operations are fused with the litharges and the residues from the cupellation of the workable lead obtained in the process of liquation; the product is a cupreous lead, which is cast into cakes or discs, and these in their turn are subjected to the series of operations which have just been described. The lead proceeding from the new liquation is, however, poor in silver, and is therefore enriched

by using it for the liquation of the black copper before passing it into the cupel.

In this series of operations, there is lost about ten to twelve per cent. of the lead employed, that is to say, forty to fifty per cent. of the weight of the black copper, or at least sixty to eighty pounds for every pound of cupel silver obtained. The loss in silver usually exceeds twenty-five per cent., regarding that silver as lost which remains in the copper. The loss in copper is five to six per cent. The *carcas* are very difficult to refine, and never yield copper of the first quality.

These results show how imperfect is this method; and hence, in the great metallurgical centres, the method now preferred is to separate the silver from the copper, either by the amalgamation of the matts or by that of the black copper. These operations are effected in a manner analogous to the Saxon amalgamation process, which has been already described, so that it will be only necessary to indicate briefly the special circumstances resulting from the nature of the materials submitted to the operation.

The amalgamation of the argentiferous black copper is practised at Schmölnitz in Hungary; it contains 0·0040 of silver. The principal difficulty to be overcome is the pulverization of the black copper: to effect this, it is heated to redness on the sole of a reverberatory furnace, and at this temperature it is placed under the pestles of a stamping machine. The matter thus crushed and broken is passed through a sieve; the finer portion is ground to a flour under iron mill-stones, the coarse is reheated and passed again under the stampers. The reduction of the chloride of silver is performed by means of copper balls, so as not to precipitate the copper from the chloride and thus render the amalgam impure, but then the loss in mercury is considerable; in certain cases it would be advantageous to saturate the liquor with lime, and to replace the copper balls by iron, which would diminish the loss in mercury. The residues of the amalgamation are remelted for black copper; their content in silver does not exceed 0·00008, and the loss in that metal is only five per cent.; the loss in mercury is 2·5 lbs per thousand lbs of black copper, or from 0·30 to 0·35 of the weight of the silver. The expenses of amalgamation do not rise to one-fourth part of those attending liquation, and the copper obtained from the smelting of the residues is of superior quality.

The amalgamation of the argentiferous matts of copper is practised at Mansfeld. The matt subjected to amalgamation at that establishment contains about fifty per cent. of copper, and 0·0025 of silver. After pulverizing the matt, it is submitted in a reverberatory furnace to a preparatory roasting, to expel the excess of sulphur; it is afterwards reduced to a thin paste with a dilute solution of sea-salt and twelve per cent. of slacked lime, which serves to saturate the sulphuric acid. The paste thus obtained is dried, ground, then roasted a second time; this is, properly speaking, the chloridation. The reduction of the chloride of silver is effected by means of iron. The residues of amalgamation are mixed, still in a moist state, with twelve to thirteen per cent. of clay, and moulded into small bricks, which are dried in a kiln, and reduced in a

furnace to black copper by adding, to form the smelting bed, twelve to thirteen per cent. of quartz, 1.5 to 2.5 per cent. of fluor spar, and thirty-two to forty per cent. of the slag from the smelting of the crude ore. The loss is eleven to twelve per cent. of the silver contained in the matts, about three-fourths of this amount remaining in the black copper, which contains 0.00046; the loss in mercury is 0.8 of a pound per thousand pounds of matt, or 1.6 pounds per thousand pounds of black copper, that is to say, about 0.35 of the weight of the silver extracted. The loss in copper is less than by liquation, and the metal is of excellent quality.

Instead of employing the different processes which have just been described, the ores of argentiferous copper might be treated in the humid way, in a manner analogous to that which is practised at Linz on the banks of the Rhine, and at Stadtberg in Westphalia, for the treatment of carbonated copper ores too poor to be treated by the ordinary processes. This method consists in treating these ores with sulphuric acid. It is impossible to submit to the direct action of this acid either calcareous or pyritous ores—the former, because a sulphate of lime would be formed which would cover or surround the copper with a paste, so as to be acted upon with difficulty; the latter, because it would scarcely dissolve in the acid. It would be necessary therefore, in these cases, to separate the gangues by smelting the crude ores, which would give them in the form of matts; and these might be roasted with a small quantity of saltpetre in furnaces, or retorts embedded in masonry, and supplied with an artificial blast. A little small wood would be sufficient to commence the heating, as the combustion of the sulphur would afterwards develop the heat necessary for the roasting. The gases proceeding from the retorts should be made to arrive, along with a current of steam produced by a separate boiler, under and around cases filled with roasted and pulverized matts; by the reaction of the steam and the gases from the retorts, sulphuric acid would be formed, which would dissolve the roasted matts; the latter might be exposed beforehand, in heaps, to the simultaneous action of the atmospheric agents and water, to transform the undecomposed sulphides into soluble sulphates, which might be removed by washing. In like manner, if the roasting of the matts did not furnish a sufficient quantity of sulphuric acid, an additional quantity might be procured by subjecting iron pyrites to the same process. A liquor would thus be obtained, containing the iron, copper, and silver of the matts; and of these the silver might be precipitated at once by metallic copper, then the copper by iron. It might be desirable, for the purpose of diminishing the consumption of copper, to almost neutralize the liquor in the first place by means of lime, and then to separate the sulphate of lime by decantation, which would be attended with no other inconvenience than impairing a little the purity of the precipitates. The silver precipitate might be purified by fusing it with a little nitre and borax; the copper could be refined for rosette copper; and lastly, the sulphate of iron, or green vitriol, might be crystallized for the market, or if dried and then slightly torrefied, it might be used for the manufacture of fuming sulphuric acid.

As regards the argentiferous black copper, it might be dissolved directly in the sulphuric acid, and the silver afterwards precipitated by metallic copper, as is practised in the mints.

IV. ORES OF LEAD, COPPER, AND SILVER.—The treatment of these ores is perhaps the most complex metallurgic operation that exists, and therefore it will be necessary to enter into some detail on the subject. Ores containing lead, copper, and silver, are divided into two great classes, according as the lead or the copper predominates. In the former case they are treated as lead ores; and, besides the workable lead, matts are obtained containing silver, copper, and lead, which are subjected to repeated fusions with substances containing more lead. Each fusion gives workable lead, which is cupelled, and the last matts are melted by themselves for black copper, which is afterwards submitted to liquation or amalgamation, to separate the silver which it still contains.

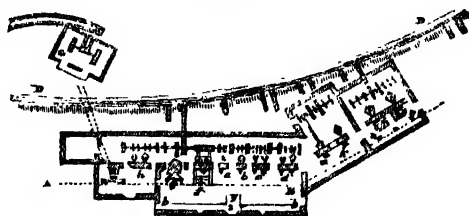
The ores which contain only a small quantity of lead are carefully assorted, and divided into at least two classes, the rich and the poor ores. The latter, according to their nature, are submitted to a *crude smelting*, with or without the addition of pyrites either crude or partially roasted, serving in the latter case as a flux, or using other fluxes if necessary, exactly as in the treatment of copper ores. The earthy gangues are thus separated, and poor matts are obtained, which are roasted once or oftener, and are then concentrated by fusion along with additional ores of the same richness. The products of this operation are scorix which are passed back into the crude smelting, and *rich matts*. These matts, after several roastings, are fused with plumbiferous substances and ores rich in silver, especially such as contain lead. The products are workable lead, which is cupelled, and matts which are subjected to a new fusion with plumbiferous matters; lastly, cupreous matts are obtained, yielding argentiferous black copper, which is treated in the manner already described. The fusion of the matts along with lead should be performed at a lower temperature than the crude smelting, in order to diminish as much as possible the loss in lead; this is the process followed at Freiberg in Saxony.

Where substances containing lead are rare or difficult to procure, the fusion of the matts with that metal is replaced by a *fusion of concentration*, and the silver is separated from the new matts by *imbibition*. For this purpose the poor lead is melted separately a little before the tapping of the matt, and is stirred with a fire-iron at the instant when the matts flow into the crucible; the lead then decomposes a part of the sulphide of silver, and passes into the matt, while the reduced silver combines with the rest of the lead and produces workable lead. If this workable lead be not sufficiently rich for cupellation, it serves anew for what is called a rich imbibition; this process constitutes the old Hungarian method. The new matt is treated over again in the same manner, and finally cupreous matts are obtained, which are fused by themselves, and yield argentiferous black copper.

Fig. 496 exhibits in plan, and Fig. 497 in vertical section, following the line A B, the Frankenscharn

works, near Clausthal in the Hartz, for the treatment of argentiferous and cupreous galenas; *a, b, c, d,*

Fig. 496.



e, f, g, denote furnaces for smelting the ores; *h,* low furnaces like the English slag-hearths for working the last matts; *k,* slag-hearths for reducing the litharge; *m,* the liquation area; *n, p,* cupellation furnaces; *x y,* a floor on which the materials for charging the furnaces

Fig. 497.



are deposited and prepared; *c,* the stamping apparatus; *v,* stream of water which impels the machinery.

Eight parts of ore in the rough state, as taken from the mine, yield one part of schlich, fit for smelting; the content of the schlich in lead is sixty to seventy per cent.; the gangue is quartzose and argillaceous. From ten to twelve thousand pounds of schlich are smelted every twenty-four hours. The furnace is attended by relays of three workmen, and a campaign lasts nine or ten weeks. The products are workable lead, which is cupelled, and matts which contain 0.001 of silver and 0.34 to 0.40 of lead. The last matts obtained are roasted several times, and are then smelted, yielding argentiferous black copper, which is submitted to liquation.

COMBINATIONS OF SILVER.—There are three oxides of silver—a suboxide, a protoxide, and a binoxide. Of these the protoxide alone forms permanent and definite saline combinations.

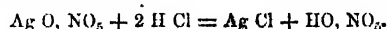
The *Suboxide of Silver*— Ag_2O —was first obtained by FARADAY, by exposing an ammoniacal solution of the protoxide to the action of air. It separates in the form of a black film.

The *Protoxide of Silver*— AgO —is obtained by adding solution of caustic potassa, or lime, or baryta-water, to the solution of nitrate of silver. The precipitate, when washed, is of a brownish-grey color, anhydrous, tasteless, but soluble, according to GRAHAM, to a small extent in pure water, free from saline matter, and has, when in solution, an alkaline reaction. It is completely reduced to the metallic state by the action of a red heat, or even by the prolonged action of the solar light. In the latter case, however, the black powder which results is possibly the suboxide. By digesting it with caustic ammonia it forms an extremely detonating compound, known as *fulminating silver*, and which, according to GAY-LUSSAC and SERULLAS, is probably an azotide of

silver. This compound, which must not be confounded with the *fulminate of silver*—to be described presently—has hitherto received no application, on account of the extreme danger which attends its preparation and management. It sometimes explodes even while still wet, and should, therefore, be prepared only in small quantities, and handled with the greatest possible caution.

The *Peroxide of Silver*— AgO_2 —was obtained by RITTER by electrifying a weak solution of silver. It deposits in acicular crystals at the positive pole, but is readily converted into the protoxide, and is of no use in the arts.

The *Chloride of Silver*—*horn-silver*— AgCl —is procured by adding a solution of chlorine, of hydrochloric acid, or of chloride of sodium, to nitrate of silver, or to any of the soluble salts of silver, with the exception of the hyposulphite. Thus—



It falls in the form of a curdy precipitate of a white color, but which, by exposure to light, becomes purplish-brown, and ultimately black. In sunshine the change is extremely rapid, more especially if any organic matter be present. It is perfectly insoluble in water, so that the minutest portion of hydrochloric acid, or of a chloride in solution, may be detected by adding to the liquid a drop or two of nitrate of silver. It is sparingly dissolved by concentrated hydrochloric acid, and thrown down upon dilution. It is insoluble in nitric acid and in cold sulphuric acid; but, when boiled in sulphuric acid, it is slowly decomposed. When dry chloride of silver is heated to dull redness in a silver crucible, it fuses, and on cooling concretes into a grey semitransparent substance, which is known as horn silver, or *luna cornea*. The presence of moisture is necessary to the blackening effect of light upon the chloride, as when dried in the dark and subsequently exposed to light under an inverted glass over sulphuric acid, no discoloration is produced.

The *Iodide of Silver*— AgI —is precipitated upon adding hydriodic acid, or a soluble iodide, to a solution of nitrate of silver. It is of a dingy yellow color, insoluble in water, and decomposed when heated with potassa. Like the chloride, it is discolored by light, and hence its use in DAGUERRE's photographic process—the plate of silvered copper intended to receive the image in the camera being prepared by exposing it in a box containing iodine. The iodide is distinguished from the chloride, not only by its yellow color, but also by its being insoluble in ammonia, which constitutes its special characteristic.

The *Bromide of Silver*— AgBr —is an insoluble yellowish substance, formed in the same manner as the iodide, and having analogous properties.

The *Nitrate of Silver*— AgO NO_3 —constitutes the most important salt of this metal. It is obtained by dissolving silver in nitric acid diluted with three parts of water; nitric oxide is disengaged, and if the silver contain copper, the solution will have a bluish tinge; if gold, that metal will remain undissolved in the form of a black powder. The solution of nitrate of silver should be perfectly clear and colorless. It is caustic, and tinges

animal substances of a deep yellow, which, by exposure to light, becomes a deep purple or black stain. It is the essential ingredient in many of the washes employed for dyeing the hair, and in the composition of the so-called *indelible* inks for marking linen; but in point of fact, cyanide of potassium will remove the black stain produced by any of the preparations of silver. The crystals are colorless, transparent, anhydrous tables, soluble in an equal weight of cold, and in half their weight of boiling water. Alcohol also dissolves about one-fourth of its weight of this salt at its boiling point, but deposits nearly the whole as it cools. When heated in a silver crucible, the nitrate fuses into a grey mass, and, if cast into small cylinders, forms the *lapis infernalis* or *lunar caustic* of the surgeons. Ivory, marble, and several other bodies may be stained black, or even silvered, by soaking them in a solution of nitrate of silver, and fully exposing them to the action of the sun's rays. A plate of copper, introduced into a solution of this salt, occasions a brilliant precipitation of crystalline silver, and the copper is oxidised and dissolved by the acid. The introduction of mercury into the solution causes a beautiful crystalline deposit of silver, known as the *arbor Diane*. To obtain this crystallization in its most perfect state, the solution should contain a little mercury; and the mercury put into it should be already combined with one-sixth its weight of silver.

Several recipes for indelible or marking inks, formed with nitrate of silver, are given in Vol. II., page 381.

Fulminate of Silver— $2 \text{ Ag O, Cy}_2 \text{ O}_2$.—This curious and dangerous compound is prepared as follows:—One hundred grains of fused and finely-powdered nitrate of silver are added to an ounce of warm alcohol, and the mixture stirred in a sufficiently large glass basin. An ounce of fuming nitric acid is then added, and presently a violent effervescence ensues, and a powder falls. As soon as this appears white, cold water is added, and the powder is immediately to be collected upon a filter, washed, and carefully dried at a temperature of 100° . In collecting and handling this powder, the utmost caution is requisite. It should be made in small quantities only, and touched with nothing hard; for it has sometimes exploded upon the contact of a glass rod even under water. The feather of a common quill serves to collect it; and it should be kept in a wide-mouthed vessel covered by paper, and by no means in a stoppered or even a corked phial, as serious accidents have arisen from its unexpected explosion. In short, one cannot be too careful in meddling with it, and its use for fulminating balls and other purposes of amusement is highly dangerous. It detonates in the quantity of a grain, or even half a grain, with great violence, when heated or touched by any hard body. The nature of this substance has been investigated by LIEBIG and GAY-LUSSAC, who have shown that it is a compound of two equivalents of oxide of silver with one of fulminic acid.—*Brande*.

Sulphide of Silver— Ag S —may be obtained by heating finely-divided silver, or plates of silver, with sulphur. It is a grey crystallizable compound, considerably more fusible and much softer than silver. It is the presence generally of sulphide of hydrogen which occasions the

tarnish upon silver, and which, though only superficial, is a great obstacle to many applications that might otherwise be made of this valuable metal.

Sulphate of Silver— Ag O, SO_3 —is deposited when sulphate of soda is mixed with nitrate of silver. It is also formed by boiling silver with its weight of sulphuric acid. It forms a white saline mass, easily fusible. Upon the large scale, small portions of gold may be most economically separated from large quantities of silver, by heating the finely-granulated alloy in sulphuric acid. The gold remains in the form of a black powder, and the sulphate of silver may be decomposed by the action of metallic copper. The silver is precipitated in a pulverulent state, and, with a little borax or other vitrifiable flux, is fused, and cast into ingots. The sulphate of copper is obtained in the crystallized state by evaporating the residuary liquid.

Hyposulphite of Silver— $\text{Ag O, S}_2 \text{ O}_2$ —is formed by digesting carbonate of silver in hyposulphurous acid. It crystallizes in permanent prismatic crystals, soluble in two parts of cold water. Hyposulphite of silver is formed by dropping a weak solution of nitrate of silver into a very dilute solution of hyposulphite of soda. A white cloud is at first produced, which redissolves on agitation. On adding more of the precipitant, the cloud reappears, and aggregates into a grey precipitate, which is the hyposulphite. The solubility of argentine compounds in hyposulphites has led to an important application of the latter in photography, for the purpose of fixing the designs by the removal of all adhering or unchanged salt of silver.

Carbonate of Silver is precipitated in the form of a white insoluble powder, by adding carbonate of potassa to nitrate of silver. It blackens by exposure to light, and is easily decomposed by heat. Carbonate of ammonia only throws down a portion of the nitrate, and forms a triple *ammonio-carbonate* of silver.

The other salts of silver are of too little importance to call for special notice.

ALLOYS OF SILVER.—Silver unites difficultly with iron. Upon fusing silver with that metal, the alloy separates into silver retaining about one-thirtieth of iron, and iron retaining about one-eightieth of silver. The latter has a peculiar hard and crystalline texture.

When silver and steel are fused together, an alloy is formed which appears perfect while in fusion, but globules of silver exude from it in cooling, which shows the weak affinity of the metals. At a very high temperature the greater part of the silver volatilizes; but a portion, equal to about one in five hundred, remains, constituting a perfect alloy known as *silver-steel*, and which is admirably adapted to the formation of cutting instruments.

Lead and silver form a very brittle dull-colored alloy, from which the lead is easily separated by cupellation. When fused lead, containing silver, is suffered to cool slowly, the lead which first concretes forms granular crystals, and is nearly pure, while almost the whole of the silver is contained in the liquid portion. The separation of the two metals in this way constitutes PATTISON'S process.

With zinc silver readily combines, producing a brittle bluish-white granular alloy. When a mixture of eleven

of zinc and one of silver is highly heated in an open crucible, it burns, and the whole of the silver is sublimed with the oxide of zinc.

With *tin* silver forms a white, hard, brittle alloy. *Antimony* also forms a brittle white alloy, the density of which exceeds the mean of its components. The greater part of the antimony volatilizes during protracted fusion; and the whole may be separated in the form of oxide by roasting.

Bismuth and silver may be combined by fusion. The alloy is brittle, yellow-white, and lamellar, exceeding in density the mean of the components. The density of an alloy of equal weights of bismuth and silver is 10·7.

Arsenic, fused with silver, forms an alloy composed of 100 silver and 16 arsenic. It is grey, brittle, granular, and by long fusion great part of the arsenic volatilizes. It may be entirely got rid of by roasting.

With *mercury* silver readily amalgamates. When red-hot silver is thrown into heated mercury, it dissolves; and when eight parts of mercury and one of silver are thus combined, a granular crystalline soft amalgam is obtained, the density of which exceeds the mean. When a solution of this amalgam in liquid mercury is squeezed through chamois leather, the excess of mercury, carrying along with it only a small portion of silver, goes through, and the solid amalgam is left behind.

Standard Silver.—The most important alloy of silver is that which it forms with copper. On account of its softness, silver is seldom employed in the pure state; by the addition of a small proportion of copper, it is rendered harder and more sonorous, while the color of the metal is scarcely impaired. A mixture of seven parts of silver and one of copper still retains a decided white color, although of a less pure tint than that exhibited by virgin silver.

The alloy of silver with copper constitutes plate and coin; the proportions are fixed by the legislature of the country in which the mixture is worked. In this country the same alloy is employed both for the purposes of the mint and the uses of the silversmith; it is composed of 11·1 of silver, and 0·9 of copper, and this mixture is known by the name of *standard silver*. A pound troy, therefore, of the standard silver of this country consists of eleven oz., two dwts. pure silver, and eighteen dwts. of copper. Its density is 10·3; its calculated density, according to the mean of the components, 10·5; so that the metals dilate a little on combining.

To prevent fraud, all silver vessels are required to be stamped by the Goldsmiths' Company, who are empowered by government to search all silversmiths' shops, and seize all articles which have not been impressed with the Hall mark of the company. For the assay of the articles, and the impression of the company's stamp, attesting its quality as standard silver, one shilling and sixpence per ounce on the weight of the object is charged. Of this amount the larger proportion is paid over to the government in the form of a tax, whilst a small sum is retained as a compensation for the trouble incurred in making the assay.

In France three different standards are employed.

The alloy used for the silver currency of the country is composed of nine parts of silver, and one of copper; for plate, a mixture of 9·5 parts of silver to 0·5 of copper is employed, whilst for small articles of silver used for ornaments, an alloy of eight parts of silver to two of copper is allowed.—*Phillips*.

The silver coins of the ancients and many Oriental silver coins are nearly pure; they only contain traces of copper and of gold.

When silver alloyed by copper, such as standard silver, is exposed to a red heat in the air, it becomes black from the formation of a superficial film of oxide of copper. This may be removed by immersion in hot diluted sulphuric acid, and a film of pure silver then remains, of a beautiful whiteness; this is called *blanched*, or *dead silver*. It is usual to employ this process in order to improve the color of objects formed of alloyed silver; the article, when heated nearly to redness, is plunged, while still hot, into water acidulated either with nitric or sulphuric acid; the external oxide of copper is thus entirely removed; and the matted appearance of the pure silver, which now forms the surface, soon gives place to a bright polish by rubbing with a burnisher. The blanks for coin are treated in this way before they are struck; whence the whiteness of new coin, and the darker appearance of the projecting portions occasioned by wear, in consequence of the alloy being uncovered. Articles of plate are often deadened or matted by boiling in bisulphate of potassa, which acts in the same way as the dilute sulphuric or nitric acid.

Silver Solder consists of—

Silver,	667
Copper,	233
Zinc,	100

SILVERING.—Almost all kinds of silvering are now usually performed by electro-chemical deposition, and for full details of the process, the reader is referred to the article *ELECTRO-METALLURGY*, Vol. I., page 800, *et sequitur*. When the term *silvering* is applied to mirrors, it generally means the application of a compound of tin and quicksilver, so that, in that sense, the word is misapplied; but, by Mr. DRAYTON's process, described Vol. II., page 227, a coating of actual silver is deposited upon the plate of glass, and in that case, therefore, the term is strictly applicable.

Silver is hammered out into thin leaves in the same manner as gold; and the account of the process given in the article on that metal, Vol. II., page 288, will therefore suffice for both. When silver-leaf is to be applied to the surfaces of bodies, the methods prescribed for gold-leaf, Vol. II., page 290, are also generally suitable. Among the metals, copper or brass are those on which the silverer most commonly operates, and frequently the white alloy of nickel. Iron is seldom silvered, but the process is essentially the same. The principal steps of the operation are summarily described by Dr. URE as follows:—

1. The *smoothing down* the sharp edges, and polishing the surface of the copper, or other metal, to be silvered.

2. The *annealing*, or making the piece to be silvered

red-hot, and then plunging it in very dilute nitric acid, till it be bright and clean.

3. *Pumicing*, or clearing up the surface with pumice-stone and water.

4. The *warming* to such a degree merely as, when it touches water, it may make a hissing sound; in which state it is dipped in very weak aquafortis, whereby it acquires minute insensible asperities, sufficient to retain the silver leaves that are to be applied.

5. The *hatching*.—When these small asperities are inadequate for giving due solidity to the silvering, the plane surfaces must be hatched all over with a graving tool; but the chased surfaces need not be touched.

7. The *charging*, the workman's term for silvering. —This operation consists in placing the silver leaves on the heated piece, and fixing them to its surface by burnishers of steel, of various forms. The workman begins by applying the leaves double. Should any part darken in the heating, it must be cleared up by the scratch-brush.

The silverer always works two pieces at once, so that he may heat the one, while burnishing the other. After applying two silver leaves, he must heat up the piece to the same degree as at first, and he then fixes on with the burnisher four additional leaves of silver; and he goes on *charging* in the same way four or six leaves at a time, till he has applied, one over another, thirty, forty, fifty, or sixty leaves, according to the desired solidity of the silvering. He then burnishes down with great pressure and address, till he has given the surface a uniform silvery aspect.

Silvering by the precipitated Chloride of Silver.—The white curd obtained by adding a solution of common salt to one of nitrate of silver, is to be well washed and dried. One part of this powder is to be mixed with three parts of good pearlash, one of washed whiting, and one and a half of sea-salt. After clearing the surface of the brass, it is to be rubbed with a bit of soft leather, or cork moistened with water, and dipped in the above powder. After the silvering, it should be thoroughly washed with water, dried, and immediately varnished. Some use a mixture of one part of the silver precipitate with ten of cream of tartar, and this mixture also answers very well. Others give a coating of silver by applying with friction, in the moistened state, a mixture of one part of silver-powder precipitated by copper, two parts of cream of tartar, and as much common salt. The piece must be immediately washed in tepid water, very faintly alkalized; then in slightly warm pure water; and, finally, wiped dry before the fire.

The inferior kinds of coated buttons get their silver coating in the following way:—Two ounces of chloride of silver are mixed up with one ounce of corrosive sublimate, three pounds of common salt, and three pounds of sulphate of zinc with water, into a paste. The buttons being cleaned are smeared over with that mixture, and exposed to a moderate degree of heat, which is eventually raised nearly to redness, so as to expel the mercury from the amalgam, formed by the reaction of the horn-silver and the corrosive sublimate. The horn-silver thus acquires a silvery surface, which is brightened by clearing and burnishing.—*Ure*.

ESTIMATION OF SILVER.—The behavior of various reagents with solutions of silver is given in a tabular form in the article on GOLD, Vol. II., page 269, to which the reader is referred. In general, the *soluble* salts of silver are recognized by furnishing a white precipitate with hydrochloric acid and the soluble chlorides, which blackens by exposure to light, and which is readily soluble in ammonia; and by affording metallic silver upon the immersion of a plate of copper. The salts *insoluble in water* are mostly soluble in ammonia; and when heated on charcoal before the blowpipe, they afford a globule of silver. A yellow precipitate on the addition of phosphate of soda and of the soluble arsenites, a red-brown by arseniates, a crimson by the chromates, and white by ferrocyanide of potassium, are further characteristics of the soluble salts of silver.

Tin and lead are the most rapid precipitants of metallic silver from the nitrate; cadmium, zinc, copper, bismuth, and antimony are more slow in their operation, and mercury still more tardy. Chloride of silver is rapidly reduced by most of the metals which form soluble chlorides, such as zinc, iron, cadmium, cobalt, and arsenic. Zinc, copper, and arsenic rapidly reduce the ammoniacal solution of oxide of silver. Of all the metallic precipitants, zinc and cadmium are the most effective; but when zinc or antimony are used, the separated silver contains those metals.

The solubility of silver in nitric acid, and the complete insolubility of its chloride in acid solutions, render the separation of silver from other metals in most instances an easy operation. When its amount is to be estimated quantitatively, the alloy or pulverized ore is dissolved in nitric acid, and the precipitation of the silver in the form of chloride is effected by the addition of a small excess of hydrochloric acid. In order that a dense precipitate may be obtained, the solution should be heated nearly to the boiling-point previous to the addition of the precipitant. When the whole of the chloride has settled at the bottom of the vessel, the supernatant liquor is carefully drawn off by means of a glass siphon; and the chloride, after being well washed by repeated decantations with water slightly acidulated with nitric acid, is transferred to a thin porcelain capsule, the weight of which has been accurately ascertained and noted down. The chloride, when placed in this capsule, is first carefully dried in a water-bath, and then heated over the flame of a gas-burner or spirit-lamp, until it has become fused, when the crucible and its contents are again weighed. The difference between the first and second weighings gives the amount of the chloride, from which that of the silver can be deduced by the simple proportion:—

As 100 : 75.27 :: K, or the weight of chloride obtained; since every 100 parts of the chloride correspond to 75.27 parts of metallic silver.

ASSAY OF THE ALLOYS AND ORES OF SILVER BY THE DRY WAY.—In this process the object sought is to obtain the silver and other metals that may be present in the form of an alloy with lead, which is afterwards passed to the muffle and cupelled in the ordinary way; in the latter, the method adopted is founded upon the simple process which has just been described.

In assaying the ores of silver, the preliminary operations to which the minerals are subjected, and the form of the cupels and other apparatus employed, have been fully described in connection with the analogous processes followed in the assaying of gold ores; and, therefore, it will be quite unnecessary to repeat them in this place. To obtain an alloy with lead, with a view to cupellation, ores of silver, in which the metals that are present exist in the form of reducible oxides, are commonly fused with a mixture of litharge and finely-powdered charcoal. The proportion of litharge employed for this purpose, says PHILLIPS, must be varied according to circumstances, as the resulting button of alloy should not be too rich, since in that case a portion of the silver is lost in the slag; nor too poor, as the cupellation would then occupy a long time, and a loss through sublimation be entailed. In ordinary cases, if four hundred grains of ore be the quantity operated on, a button of two hundred grains will be a very convenient amount for cupellation; and this may be obtained by the addition of three hundred grains of litharge, and from seven to eight grains of finely-powdered charcoal. The whole is to be well mixed with two hundred grains of carbonate of soda, on a sheet of highly-glazed paper, and afterwards introduced into an earthen crucible, of which it should not fill more than two-thirds the capacity. This is now covered with a thin layer of borax, and fused in an ordinary assay furnace—care being taken to withdraw it from the fire as soon as a liquid and perfectly homogeneous slag has been obtained, as the unreduced litharge would otherwise be liable to cut through the pot and spoil the experiment. When it has sufficiently cooled, the crucible is broken, and the button of alloy obtained is passed to the cupel. When other minerals than oxides or carbonate are to be examined, the addition of charcoal, or any similar reducing agent, becomes in many instances unnecessary, as litharge readily attacks all the sulphides, arsenio-sulphides, *et cetera*, and oxidises nearly the whole of their constituents, with the exception of silver, whilst a proportionate quantity of metallic lead is at the same time set free. The slags formed in this way contain the whole of the excess of litharge added; and the button of alloy produced is subjected to cupellation in the usual manner.—*Phillips*.

In the assay of alloys of silver by cupellation, the directions which are given in Vol. II., page 303, in connection with the assaying of gold, render unnecessary a repetition of all the details of the process, which consists, as there stated, in the oxidation of the lead and other oxidisable metals, and their absorption by the cupel. From the circumstance that the plate and silver money of all European nations are alloyed with copper, the mixtures of these metals are those which most frequently engage the attention of the assayer; and the point to be chiefly attended to is the amount of lead necessary to be added to perform the cupellation efficiently. This amount should be greater, in proportion as the quantity of copper is more considerable; but, in cupelling an alloy of silver and copper, the same amount of lead cannot safely be added as in treating an alloy of copper and gold, as the greater volatility of the silver would cause a consider-

able loss of that metal before the whole of the lead could be absorbed. In this case, therefore, the following table, showing according to D'ARCY, the amount of lead necessary to effect the proper cupellation of various alloys of silver and copper, must be substituted for that given at the page above referred to:—

Standard of silver.	Amount of copper alloyed.	Quantity of lead necessary.	Quantity of lead in relation to that of copper.
1000	0	3-10th*	0 to 0
950	50	3	60 to 1
900	100	7	70 to 1
800	200	10	50 to 1
700	300	12	40 to 1
600	400	14	35 to 1
500	500	16 to 17	32 to 1
400	600	16 to 17	27 to 1
300	700	16 to 17	23 to 1
200	800	16 to 17	20 to 1
100	900	16 to 17	18 to 1
Pure copper	1000	16 to 17	16 to 1

* Even with pure silver it is found necessary to add a little lead on the cupel, as the button would not otherwise assume the rounded form which is required.

In this table the numbers in the third column, which express the quantity of lead necessary to be added in each case, are multiples of the weight of alloy on which the operation is performed. Hence, in the third line, for example, in which the alloy consists of 900 of silver, and 100 of copper, for each grain of alloy taken, seven grains of lead will be necessary; and as each grain of alloy contains only one-tenth of its weight in copper, it follows that the ratio of the lead to the copper is as seventy to one. It will be observed that, even with pure silver, it is found necessary to add a little lead on the cupel, the reason of which is, that the button of silver would not otherwise assume the rounded form required. It will be remarked, also, that here, as in the table given for an alloy of gold and copper, the proportion of lead to be employed for a silver alloy below the standard of 500, remains constantly the same.

Although silver is not appreciably volatilized when melted alone, yet it is so to a certain extent in the presence of lead; and therefore the cupellation should be made at the lowest temperature at which the absorption of the litharge can be effected; and even when every precaution is used, there is always a loss of silver in cupellation, for which allowance must be made in finally calculating the per centage. The table adopted for this purpose at the French mint is given in Vol. II., page 304, to which the reader is referred.

When other metals besides lead and silver are present in an alloy, the cupel usually affords indications, from which it is easy to judge of their nature, and roughly of the amount in which they exist. Mr. PHILLIPS, in his excellent manual of metallurgy, gives the following directions for this purpose—Pure lead stains the cupel a straw-yellow color, sometimes verging on orange. Copper gives a grey or dark-brown tint, according to its quantity. Iron produces a black stain, which is chiefly formed shortly after the commencement of the operation, and gives rise to a dark ring around the sides of the cupel. Zinc leaves a yellowish stain on the cupel, and produces, during the process of cupellation, a luminous white flame and abundant fumes of the same color, which carry off

with them a considerable amount of silver is produced, a grey slag, and a silvery layer, a spongy yellow scum, which causes the circumference of the cupel to effloresce and split off. The two last-named metals render the cupellation of the alloys in which they exist extremely difficult, and necessitate the employment of a large quantity of pure lead, in order to carry off the insoluble oxides formed. When assays of alloys containing silver are frequently to be made by cupellation, it will be found extremely convenient to keep in the laboratory a supply of poor lead, ready weighed out into pieces of fifty and one hundred grains; by this means the standard of the lead being previously known, it becomes easy, by merely counting the number of pieces added, to know exactly what deduction is to be made for the silver in the poor lead at the termination of the cupellation.—*Phillips*.

Humid Method of Assay.—The operation is the same as that described above under estimation of silver, except that instead of collecting and weighing the argentiferous compound, graduated test liquors are employed, and the silver estimated from the volume of such solutions required to precipitate the silver completely. Although the method by cupellation was found to be convenient, where a number of assays were required to be conducted at the same time, and was therefore, until of late years, exclusively adopted at the different mints, yet the results obtained by this method not being perfectly accurate, the French Government in 1829 appointed a commission for inquiring into the subject; and GAY-LUSSAC, who was one of the commissioners, proposed the adoption of the liquid method of assay, which is now generally practised, not only at the Parisian mint, but also at the similar establishments of this and other countries. Not only is greater accuracy obtained, but by successive improvements in the apparatus, the humid process is now conducted with greater facility and despatch.

In this process the standard of the alloy of silver and copper is determined by means of a solution of chloride of sodium, the strength of which has been accurately determined beforehand. Common salt, without any preliminary purification, is employed for this purpose; and the strength of the solution is so regulated, that a decilitre thereof will exactly precipitate one gramme of pure silver. In proceeding to make an assay, one gramme of the alloy to be examined is dissolved in five or six grammes of nitric acid, and to this is added from a graduated burette the standard solution of common salt, until no further precipitate of the chloride of silver takes place. When, in adding the precipitant, the point of saturation seems to be nearly attained, the bottle must be well shaken after the addition of each successive drop of the solution, in order that the liquor may become clear by the precipitation of the chloride of silver formed. When the whole of the silver has thus been thrown down, the exact quantity of the solution of chloride of sodium employed in its precipitation is read off from the graduated scale; and, by the amount used, the per centage of silver present is at once indicated.

When great accuracy is required in making the assay of a silver coin or a piece of plate, the composi-

tion of which is approximatively known beforehand, two distinct solutions of chloride of sodium are employed:—The first, which is termed the *normal solution*, is of such a strength that one decilitre will precipitate exactly one gramme of pure silver; the second, called the *decimal solution*, is only one-tenth of the strength of the first; and, consequently, a litre of it is required to effect the precipitation of one gramme of silver.

To explain the details of the process, let it be supposed that a piece of silver money of the French coinage is to be assayed, and which, in order to be of the legal standard, should contain eight hundred and ninety-seven thousandths of pure silver. Instead of this, suppose the alloy in question to contain only eight hundred and ninety-six thousandths of silver, so that 1.116 gramme of the mixture corresponds to one gramme of pure silver. This quantity is cut off the coin, accurately weighed, and put into a bottle that admits of being perfectly closed by a glass stopple, where it is dissolved in from five to six grammes of pure nitric acid; and as soon as the solution has been completely effected, one decilitre of the normal solution of salt is introduced. If the alloy contain exactly as much silver as was supposed, namely, eight hundred and ninety-six thousandths, the whole of that metal will be precipitated by the quantity of solution added, and the supernatant liquor will contain no traces of chloride of sodium in excess. But if the standard be higher than was supposed, there will still remain a portion of silver in solution; and if it be less, the whole of the silver will have been precipitated, but the liquor will contain an excess of chloride of sodium.

To ascertain which of these effects has been produced, the bottle is carefully closed with its glass stopple and briskly shaken, until the precipitate has subsided, and the solution become clear. A cubic centimetre of the decimal solution, capable of precipitating 0.001 gramme of pure silver, is then introduced. If any silver remain in solution, the liquor becomes cloudy; and after being again shaken, another centimetre of the decimal solution is added. If the liquor still becomes turbid, it is again shaken and allowed to become clear; a third centimetre of the decimal solution is poured in; and so on until no further cloudiness is produced by the addition of the decimal solution. Supposing that five of the cubic centimetres of the decimal solution, successively added, have produced a precipitate, while the addition of the sixth has not affected its transparency; it may be concluded that, after the precipitation of one gramme of pure silver by the decilitre of normal solution, the liquor still contained at least four-thousandths of a gramme of silver. But as a cloudiness was produced by the fifth cubic centimetre of the decimal solution, and none by the sixth, it is evident that the liquor did not contain more than five-thousandths of a gramme of silver; and, therefore, by adding $4\frac{1}{2}$ thousandths, the exact result is certainly attained within one half-thousandth of the truth. The standard of the alloy under examination will therefore be $896 + 4\frac{1}{2} = 900\frac{1}{2}$ thousandths.

When, on the contrary, the first cubic centimetre of the decimal solution produces no precipitate in the solution of silver, which has already received the decilitre

into London, and sold under the title of *arrow-root prepared by the native converts at the missionary stations in the South Sea islands*. The tuberous roots, which yield a highly nutritious fecula, are washed and scraped to remove the outer skin, then reduced to a pulp by rubbing on a kind of rasp made by wrapping coarse twine from the cocoa-nut fibre tightly round a board, or, as ELLIS states, on a piece of coral; the pulp is then washed with sea-water on a sieve made of the fibrous web that protects the young frond of the cocoa-nut palm. After the deposition of the fecula the liquor is drained off, the sediment made into balls and dried in the sun from twelve to twenty-four hours, then broken up, and the desiccation finished in the sun. This starch has a slight musty odor, though in color it resembles genuine arrow-root. Its particles appear smaller than cassava starch; they are circular, muller-shaped, and polyhedral, having a small circular hilum, and but few and not very distinct rings.

There are a great many other tropical plants from which starch could be extracted, such as the unripe fruit of the plantain and banana, and the tuber of the *dioscorea* or yam, the former of which is stated to afford seventeen per cent. of starch, and the latter nearly twenty-three per cent.

Tous-les-mois.—The starch or fecula bearing this name is allied to the preceding. It is extracted from the tubers of the *Canna edulis*, a native of the West Indies. The seat of its manufacture is principally St. Kitts, whence it was introduced into England in 1836. From the account of Mr. WORDSWORTH, it appears that the plant grows to the height of four feet or more, and yields a tuber three or four times as large as average-sized potatoes. The fecula is extracted to the amount of twelve and a half per cent. of the tubers by rasping and subsequent washings in the ordinary way. Its granules are much larger than any other kind of starch, not excepting that of the potato; and consequently it may be readily distinguished from the latter by the practised microscopist. In bulk it has a satiny, glistening appearance, somewhat resembling potato starch, but devoid of the dead white of the genuine arrow-root.

PEREIRA gives the following as the principal distinguishing characteristics of this and potato fecula:—

1. The particles of potato starch are smaller and more irregular in size than those of *tous-les-mois*.

2. The larger particles of potato starch are more irregular in shape than those of *tous-les-mois*: the latter are more constantly rounded-oblong, or ovate-oblong; the former more oval, often approximating to the shape of an oyster or muscle shell, or a triangle with rounded corners, and frequently gibbous or tumid at different parts of their surface.

3. The rings seen on particles of *tous-les-mois* are fine, regular, uniform, concentric, and crowded; those of potato starch are coarser, irregular, often eccentric, irregularly drawn out, distorted, or more and unequally distant from each other. In potato starch a greater number of complete rings are visible, and may be traced round the hilum even in case of many of the larger rings. With *tous-les-mois* only a few of the smaller rings can be thus distinguished.

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4. The hilum is situated nearer to the end of the corpuscle in *tous-les-mois* than that of fecula.

Lastly, when viewed with polarized light the cross is generally less regular in the potato starch grains than those of the *tous-les-mois*.—*PEREIRA*.

Sago.—This is the title of a starch extracted from several varieties of palms very common in Sumatra, Borneo, and other islands of the Indian Archipelago; the word is derived from the Malay name, *sagu*, for the palm and the farina itself. The genuine sago is imported into England from Singapore in large quantities, but a fictitious kind is made at home in many of the starch manufactories from fecula and wheat starch. The real plant which affords the sago is still undefined, for several of the species are known to yield it, those of the *Sagus* and *Sagurus* being the most important. The *Sagus rumphii*, *Sagus inermis*, *Hydrocylon sagu*—the *rambija* of the Malays—*Corypha urens*, or sago palm of Assam, *Doraseus gomuti*, and a few others are the most resorted to, together with several species of *Zamia*, *Corypha*, and *Mauritia*. In most of these trees the pith is so abundant as to constitute a great part of the bulk of the entire stem, which from its rapid growth often attains to a thickness of a foot or more in diameter in the course of six or seven years. From such a tree it is stated that as much as three hundred-weight of sago can be obtained.

The method adopted for extracting the matter from the tree and separating the starch from it is somewhat different from that followed in preparing arrow-root starch; but the mode of preparing the sago bears so much resemblance to the European system of preparing grain starch, that it will be unnecessary to enlarge upon it in detail. In the Moluccas, the tree when sufficiently matured is cut down near the root, and then divided into portions averaging seven or eight feet in length, which are split open and the pith extracted. By various means—such as pounding in a mortar, *et cetera*—this substance is reduced to a coarse powder, which is agitated with water and submitted to the usual siftings and washings; the farina is then allowed to deposit, and on drawing off the fluid and drying the residue, the *raw sago meal* is obtained. From this the granulated and pearl sago is prepared, after submitting it to a bleaching process preparatory to granulation. To bleach it, the sago meal or flour, mixed with water to the consistence of cream, is exposed in close vessels to the agency of sulphurous acid or chlorine, or to a solution of hypochlorite of lime or soda, and afterwards well washed; a little sulphuric acid being mixed with the washing water when the hypochlorite is used.

In New Guinea the granulation is performed by putting the sago meal with a clear liquid is then racked through coarse bone ing. in the filters, H, H, the deposit of sulphate of lime placed so thrown upon cloth filters, where it is drained. The sirup as it flows off from the filter, that during its viscosity of 1.11 to 1.122, is retained in the stirred and turned from which it is raised by a pump or is quite white at the reservoir M; from this it is somewhat pellucid in the horizontal channel, m, by numerous that the tapioca sago channel, p, and tube, q, into

action of heat, but so well managed is the operation, that none of the substance is in the least charred. He adds that some of the sago of the islands presents no appearance of having been heated, and in the case it is supposed that the granulation is effected by a mill. Two kinds of granulated sago are known in commerce—the common brown or red, and the white or pearl sago. The color is attributed by PLANCHE to the red matter contained in the variety of palms from which the starch is extracted, and by the application of the heat required for granulation altered to a grey, which is the usual color of unrefined sago. Formerly the imported article presented a great inequality of aggregation, varying from very small grains to that of pearl barley or peas, the substance being, however, identical in both, and evidently composed of cemented particles of sago meal. Pearl sago dates from a recent period; CRAUFORD, whose account of it was the first published, states that the method of manufacturing it was discovered by the Chinese of Malacca, a few years previous to 1820, the year in which he wrote. It is met with in pearl-like grains of an irregularly globular form, ranging from the size of a poppy to that of white mustard seed or a little larger. The surface of the larger grains is generally smooth and even, but that of the smaller kinds is uneven and somewhat tuberculated. Under the microscope, the particles of this variety present the same appearance as that of the colored product and sago meal, except that the most of them appear ruptured from the action of the heat. Sago when granulated possesses the property of considerably swelling in hot water or other liquids, without losing its adhesive power; hence the grains appear translucent and gelatinous, but not as slimy globules. The following table by PLANCHE exhibits the quantity of water which the different varieties of sago met with in commerce take up in softening, as also the chief distinctions of the farina itself:—

Source.	Color.	Water absorbed in softening. Per cent.
Maldines,....	Grains, mostly red, some white,...	150
Sumatra, ...	Grains, white or dirty-white,....	134
New Guinea, ...	Grains, brick-red or lighter,	121
Moluccas,....	Red variety,	130
Do.,	Grey,	109
Do.,	White,	164

Of late years, more especially in Germany and France, considerable quantities of artificial or fictitious sago have been manufactured from inferior starches, such as fecula. The process is simple, consisting merely of submitting the starch after air-drying to a temperature of 212° on iron plates, and thus causing the granules to swell to such a degree that some of them burst, when the gummy matter forms a cement that envelopes other granules. Care must be taken that the heat does not destroy the action of each successive drop of the solution, in order that the liquor may become clear by the precipitation of the chloride of silver formed. When the water rolling the silver has thus been thrown down, the exsular form of the solution of chloride of sodium and starches are its precipitation is read off from the grains necessary in and, by the amount used, the per cent as will facilitate the present is at once indicated. granules at the com-

When great accuracy is required insure its cementation. assay of a silver coin or a pie

DERIVATIVE PRODUCTS FROM STARCH.—Two products are obtained from starch which are very extensively employed, not only by themselves, but also for the production of other substances of considerable importance. These are *dextrin* and *glucose*, of each of which it will be necessary to give a short account.

Dextrin.—This substance has been briefly described under the term **BRITISH GUM** in Vol. II., page 313; but its importance deserves that some further details should be given here. It is a substance immediately produced from, and isomeric with starch, and is so called from its property of diverting to the right a ray of polarized light transmitted through its solution. It is soluble in water and in dilute spirit of wine, but insoluble in absolute alcohol. A solution of iodine does not alter its color in solution, except when the transformation of the starch is incomplete, in which case it produces a violet, shading off to a red tint. When the colorless solution of this substance in hot or cold water is evaporated, a viscous mass is obtained, which, on being dried, yields the dextrin in a mass somewhat resembling gum-arabic; it is similar also in its properties, so much so that in many applications it is substituted for gum-arabic at a great saving; and hence the trade that has sprung up of late years in this substance under the title of *British gum*, *Leicocome*, *et cetera*. It does not, however, like gum-arabic, yield derivatives, such as mucic acid and the like, when treated with nitric acid and other agents, and in this respect a marked chemical distinction is established between the two substances. On the methods resorted to for its preparation, the Editor has nothing to add to the details given at the page above referred to.

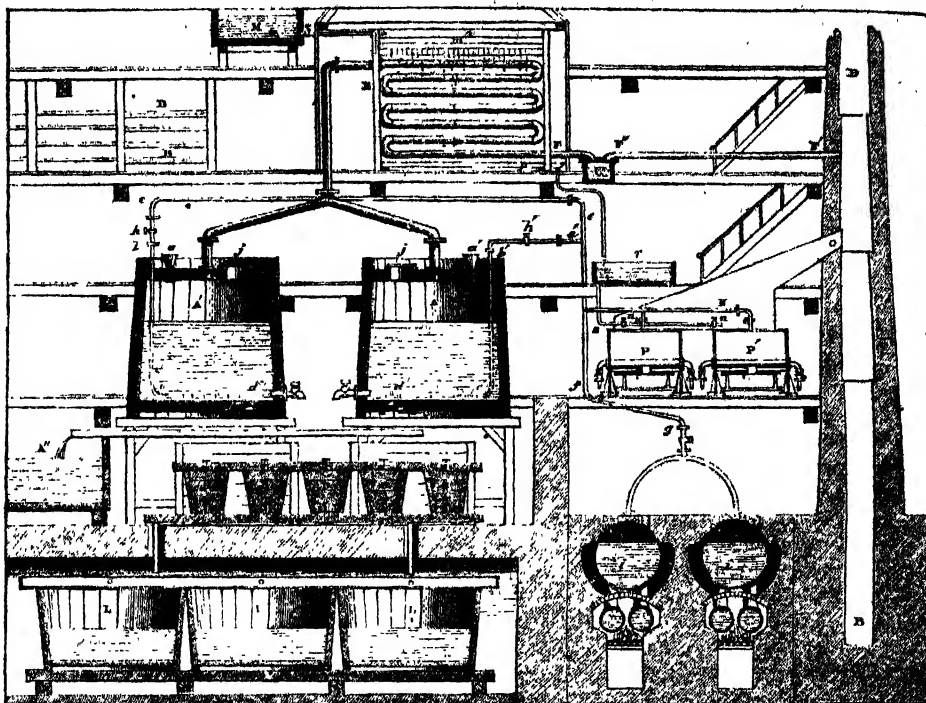
Glucose.—In starch factories, especially on the Continent, a considerable quantity of starch or potato fecula is converted into glucose—a species of sugar which is found in many kinds of fruit, especially the grape, and into which all other varieties of sugar, whether it be the product of the cane, maple, or beet, is readily resolved by the action of acids and other chemical agents. The chief use to which glucose is applied on the Continent is for the manufacture of beer, and a coarse kind of alcohol, which is said to be extensively converted into French brandy by the addition of oil of raisins, coloring matter, *et cetera*. There are two methods by which the starch, or rather dextrin, is converted into glucose; the one is well exemplified in all the breweries and distilleries of the kingdom, where thousands of tons are annually formed in the preliminary stages of malting and mashing; the other consists in the use of sulphuric acid, which is a more expeditious method, and gives a purer product than when the conversion is effected by means of diastase. The process is naturally divided into six stages, namely, the conversion of the starch into dextrin, the saccharification of the dextrin, the settling of the liquid, the evaporation, the filtration, and the concentration. PAYEN describes the apparatus and operations connected with it as follows:—

The saccharification of the starch is effected in large tubs or vats, A A'—Fig. 553—constructed of stout wood, to contain two thousand eight hundred gallons. In one of these, A', a lead pipe, b c d, coiled at the bottom, is placed, the circular portion being cut or

perforated for the introduction of steam to heat the acidulous water with which it is two-thirds filled; the steam from the generator, *i*, is admitted to it at plea-

sure by means of the pipe, *b f e g*, and stopcock, *h*. During the operation the vat is covered, and the disengaged vapor conducted to the chimney, *B D*; but

Fig. 53.



before escaping it may be utilized in evaporating the sirup by conveying it through serpentine pipes, *E, F*. By such arrangements the disagreeable odors resulting from the evaporation of the oil of the starch are considerably abated, being partly condensed in the serpentine pipe, so as to flow off with the water produced from the steam into a vessel interposed between the pipes, *F, G*, and partly carried away by the pipe, *F', F''*; or the uncondensed vapors may be conducted into the fire where any remaining traces of essential oil are consumed, and thereby the nuisance is almost entirely prevented.

When it is proposed to convert two tons of fecula in such an apparatus, the substance is suspended in portions of two hundredweight in a trough or tub, with twenty-two gallons of water, and when thoroughly steeped, it is introduced by a funnel, *a*, in quantities of four to five gallons at a time, into the large tub or vat, which should be previously charged with about thirty-two barrels of water, and three quarters of a hundred of sulphuric acid agitated with it, the whole being raised to 212° by forcing steam into it. This temperature is maintained till all the fecula is introduced, and it is found that the transformation is accomplished in thirty or forty minutes after the last portion of the starch has been added. The point at which the change is completed is easily ascertained by simply testing a few drops of the clear liquid with a drop of a solution of iodine, when, if the saccharification be effected, no coloration takes place; in the contrary case the cha-

racteristic violet of iodide of starch manifests itself. After the conversion into glucose, the introduction of the steam is suspended, and the next operation is the saturation of the free acid by means of carbonate of lime, and the consequent precipitation of sulphate of lime. The latter being but sparingly soluble, most of it falls to the bottom. It requires from ninety to a hundred pounds of chalk to saturate the whole of the free acid; and this must be introduced gradually to guard against the evolution of too much carbonic acid at once. If an excess of lime be used, it prevents the solution from clarifying so readily as when the sulphuric acid is barely taken up; this is shown by the cessation of effervescence, and the inability of the liquid to change the blue color of litmus to more than a feeble purple tint. When the saturation is completed, the mixture is either permitted to repose in the same vessel, or if it be required to operate upon another batch at once, it is drawn off into the lower vat, *A'*, where it is left at rest during twelve hours; the clear liquid is then racked through coarse bone black in the filters, *H, H*, the deposit of sulphate of lime being also thrown upon cloth filters, where it is drained and washed. The sirup as it flows off from the filter, having a density of 1.11 to 1.122, is retained in the reservoirs, *L, L, L*, from which it is raised by a pump or a chain of buckets to the reservoir *M*; from this it is distributed in a horizontal channel, *m*, by numerous lateral apertures upon the serpentine evaporator, *E F*, and then flows by a channel, *p*, and tube, *q*, into

a receiver, *r*, whence it can be drawn at will by the tube, *e*, and stopcocks, *n*, *n*, into the boilers, *P*, *P'*, which are heated by steam, and in which the liquid is concentrated to 1.26 specific gravity. The sirup thus obtained, after reposing a sufficient time to allow the sulphate of lime precipitated by the evaporation to subside, is fit for the brewer or distiller; but if intended for the confectioner or liqueur-maker it should be allowed to rest for twenty-four hours, filtered when cold through coarse bone black, and casked immediately. When it is desired to obtain the glucose in a solid state, the evaporation is carried so far as to concentrate the sirup to 1.38 or 1.39 specific gravity—73° to 74° Twaddell; it is then poured into the cooler, where it is left till the crystallization commences, and thence transferred to the tuns in which the solidification is effected.

Of late years, instead of preparing the sugar in an amorphous solid mass, as by the preceding method, it is obtained in grains or regular crystals. The process for converting the starch into sugar is the same as that already described; but care is taken to do it more thoroughly, since any excess of dextrin in the sirup is found to prevent crystallization. After the acid has been neutralized, and the lime salt removed by deposition, *et cetera*, the saccharine liquid is decolorized, and concentrated to 1.300, or 60° Twaddell, in summer; and 1.262 or 53.5° Twaddell, in winter. At these stages it is racked off into large reservoirs where the lime salts settle down; and during this period it is necessary, in order to prevent any fermentation, that the liquid be cooled either by circulation of air or of cold water in a coil placed in the vessel. After thirty-six to forty hours, the sirup, being clarified and cooled to about 65°, is put to crystallize in ordinary tuns furnished with a false bottom placed over the lower one, which is pierced with a number of holes that are stopped with wooden pegs. These tuns are placed on stages along the walls of the room, twelve to fifteen inches above the floor. A sheet of lead, or large canal or sluice, reaches along each range of crystallizing tuns. To avoid the fermentation of the sirup, which in summer often prevents the crystallization, six or seven ounces of sulphurous acid solution are added to the content of each tun. At the end of eight or ten days the crystallization commences and goes on, the crystals depositing in succession. When the bulk of two-thirds of the liquid becomes a mass of crystals, the pegs in the lower bottom are withdrawn, and the still fluid portion is permitted to drain off, the operation being quickened towards the end by tilting two adjoining tuns against one another. The drainings are conducted to the converting tun, where any dextrin the liquor may still contain is saccharified.

The desiccation of the drained sugar was long a work of difficulty, the moisture of the air being sometimes sufficient to convert it again to sirup, which, with the heat of the factory, melted and agglomerated the remaining portion. M. FOUSCHARD has obviated these inconveniences by furnishing the tuns or tubs, *s. s.*, with tables of plaster of Paris, which absorb the portion of the interposed sirup. This very much quickens the desiccation of the crystals, especially in

a current of air heated to 77°, taking care that the granules are not thereby soldered together. There is, however, a certain amount of the crystallized mass which has to be submitted to a second solution, namely, that which is agglomerated on the end of the loaf resting on the plaster; this must be separated, and the sugar extracted from the sulphate of lime, by grinding them between cast-iron cylinders, and dissolving in the ordinary way.—*Payen*.

Glucose crystallizes in grains formed of a number of lamellar plates radiating from a common centre, and thus forming a kind of bristling spheroid of lamellar points. It has only one-third the sweetening power of cane sugar, whilst it is once and a half less soluble; at 212° it melts in its water of crystallization, which characteristic allows of its recognition when in certain proportions in cane sugar. It may also be detected by the property which glucose possesses of forming definite compounds with alkaline and earthy bases, which compounds suffer decomposition, and become strongly colored brownish, at a temperature between 160° and 212°, which is not the case with cane sugar under like circumstances.

Glucose is composed of $C_{12}H_{12}O_{12} \cdot 2H_2O$, differing from starch, $C_{12}H_{10}O_{10}$, only by an addition of two equivalents of the elements of water, and two equivalents of the water of crystallization, with which, however, it parts when carefully exsiccated, leaving the compound of the composition $C_{12}H_{12}O_{12}$.

STRONTIUM.—Although less abundantly diffused, it resembles barium both in its chemical and geological relations. Like it strontium is never found native, but only as *carbonate* and *sulphate*. It was first recognized by HOPE in 1792, in the mineral *strontianite*, so called from Strontian in Scotland.

Pure strontium was first made by DUNSEN and MATTHIESSEN in 1855; impure by DAVY in 1807. It is prepared by electrolysis from chloride of strontium. It is a golden-yellow metal, of considerable metallic lustre, harder than lead, and ductile. It melts at a red heat. Heated in air, it inflames and burns with a bright lustre in oxide. In dry air it remains untarnished; but it decomposes water, even at ordinary temperatures, with singular vehemence. Fuming nitric acid does not attack it; but dilute acids oxidize it readily. It burns in chlorine, iodine, bromine, and sulphur atmospheres, producing the corresponding compounds. Strontium has a specific gravity of 2.542, and an equivalent weight of 44. It is only in a strictly scientific light that this metal and its compounds are of any importance, excepting the chloride and nitrate, which are much used by pyrotechnists. The chemical symbol of the metal is *Sr*.

A few of its principal compounds are briefly described in the following:—

OXIDE OF STRONTIUM—Strontia.—This base is most easily obtained by igniting the nitrate. It is greyish-white, and of specific gravity 3.932. It is neither fusible nor volatile. For water it shows powerful affinity, and forms a *hydrate*. This is soluble in fifty times its weight of cold, and 2.4 parts of boiling water. From the latter it separates in crystals belonging to the square prismatic system. Nine equivalents

of water are easily expelled by heat; but it requires a temperature approaching white heat again to render the hydrate anhydrous. Both strontia and its hydrate readily absorb carbonic acid. The symbol of strontia is SrO , and the equivalent 52; the symbol of the hydrate is $\text{SrO}, 9 \text{HO}$.

CARBONATE OF STRONTIA is found native as strontianite, both massive, and in forms belonging to the square prismatic system. It is most readily prepared pure by precipitating the nitrate or chloride with carbonate of ammonia. The artificial carbonate is beautifully white and soluble in one thousand five hundred and thirty-six parts of boiling water. It is more soluble in aqueous solution of carbonic acid, and separates in needles when evaporated. Heated to bright redness in a stream of watery vapor it loses its carbonic acid, and becomes changed into strontia. The symbol is SrO, CO_2 ; Eq. 74.00; specific gravity, 3.605.

SULPHATE OF STRONTIA is the celestine of mineralogists. Sometimes massive, it is often found beautifully crystallized in prisms isomorphous with sulphate of baryta. Artificially it may be prepared by precipitation from any of its soluble salts, either by sulphuric acid or a soluble sulphate. It has the form of a white tasteless powder, soluble in fifteen thousand parts of cold, and three thousand eight hundred and forty parts of boiling water. In solutions of common salt it is slowly but completely soluble. A solution of sulphate of strontia precipitates salts of baryta. The symbol is SrO, SO_3 ; Eq. 92.00; specific gravity, 3.95.

NITRATE OF STRONTIA separates from concentrated solutions in transparent colorless octohedra, soluble in five parts of cold, and half their weight of boiling water; insoluble in alcohol. It has a sharp, cooling taste, and decrepitates in the fire, leaving strontia. At low temperatures it crystallizes out from more dilute solutions with five equivalents of water. Nitrate of strontia is much used by pyrotechnists to produce a splendid crimson flame. A mixture of forty parts of the nitrate, five of chlorate of potassa, thirteen of sulphur, and four of the sesquisulphide of antimony, is found a good one in practice, but great care is necessary in the admixture. The symbol is SrO, NO_3 ; Eq. 106.00; specific gravity, 2.704.

On the large scale the nitrate is prepared by heating pounded celestine with one-third of its weight of bituminous coal, dissolving the resulting sulphide in water, and decomposing with dilute nitric acid.

CHLORIDE OF STRONTIUM is in long, six-sided needles, deliquescent in moist air, and soluble in three-quarter parts of cold water. It imparts an intense crimson color to flame. In alcohol it is also soluble. When heated, the chloride melts and becomes speedily anhydrous. Ignited in air, it loses chlorine and absorbs oxygen. The chloride of strontium is most easily prepared by dissolving the sulphide in water, and decomposing with hydrochloric acid. The symbol for the salt is SrCl , 6 HO .

General Character of the Salts of Strontia.—They are colorless; not poisonous, like most of those of barium. Before the blowpipe they communicate a crimson color to flame. Neither hydrofluosilicic acid nor

hyposulphite of soda precipitates them. The chromate of strontia is sufficiently soluble to be employed as a test for baryta; but oxalic acid produces immediate turbidity in them. On addition of sulphate of lime to a solution of a salt of strontia, there arises gradually a white precipitate of sulphate of strontia; immediately when heated.

Strontia is always determined in analysis as sulphate or carbonate; one hundred parts of the former contain 56.52 of strontia, and of the latter 70.27 parts of this base.

SUGAR.—*Sucre*, French; *Zucker*, German; *Saccharum*, Latin.—Sugar seems to come more directly from the Persian *Shukkur*, which is nearly the same as the English pronunciation. The Arabic name is similar, and the probable origin of both is said to be the Sanscrit *Sarkara*. In the old Assyrian and Phœnician languages there was no letter *k*, but both nations called the substance *suicar* or *suicra*. It is said by HUMBOLDT to have been known in very early times in China. It is probable that in early historic times it was brought as a luxury and a curiosity into Western Asia and Europe. The Hebrew word for being intoxicated is *Shacar*, and strong drink *Shecar*. These words were believed to have an intimate connection with sugar; but this could only occur in a country where sugar was so well known that its ready passage into alcohol was familiar. Such was not the case in Western Asia or Syria and the surrounding countries in known times, although it may have been so at an earlier period. In the Bible is mentioned *sweet calamus* two hundred and fifty shekels; and *calamus* and *cinnamon* in SOLOMON'S Song; *sweet cane* in ISAIAH, and in JEREMIAH and EZEKIEL. There is little difficulty in believing the scriptural writers to be the earliest who allude to sugar. Persons in frequent communication with the East were sure to obtain its products before the Greeks. HERODOTUS speaks of manufactured honey, supposed to mean sugar; and STRABO mentions that NEARCHUS, one of ALEXANDER'S admirals, speaks of a reed which yields honey without bees in India. THEOPHRASTUS mentions it as a honey obtained from a reed which grow in moist places in Egypt, and had a sweet root. This sweet root has been used as a proof that he did not allude to the cane. The mention of moist places also is an objection; but so many canes do grow in moist places that one readily forgives this error and others, seeing that the fact of sweet matter from a cane is so distinctly spoken of. THEOPHRASTUS speaks of honey from reeds, evidently cane sugar. ERATOSTHENES alludes to roots in India sweet to the taste even when boiled, as if it were the custom to boil them to remove the sugar. VARRO speaks of the juice of an Indian root so sweet that, when pressed out, no honey can contend with it. DIOSCORIDES says that there is a kind of honey called *saccharus* which is found in reeds in India and Arabia Felix, having the appearance of salt; but it was only used in medicine. If found in Arabia it well have been known early in Syria. PLINY says that there is a kind of honey which collects in reeds, white like gum, and brittle to the teeth; the larger pieces about the size of a filbert, and only used in medicine. STATIUS speaks

of boiling canes in Ebosita; but that place is not known. *ARRIAN* mentions it as an article of Indian commerce; and *ÆLIAN* speaks of it as pressed from reeds on the Ganges. It is well to add that *DR. ADAM*, the learned editor of *Paulus Egineta*, says that the *saccharum* of *THEOPHRASTUS*, *DIOSCORIDES*, *GALEN*, *STRABO*, and *PLINY* was a concretion formed on various reeds, but especially on the bamboo cane; also, that *MOSES CHORENENSIS*, fifth century, first mentions the boiling of canes. This may account for the bitterness and medicinal qualities mentioned by *DIOSCORIDES* and others. *ALBERTUS AGNENSIS* relates that the crusaders found sweet honeyed canes in great quantity in the meadows near Tripoli in Syria, which reeds were called *Zucra*. Those the crusaders sucked, and were much pleased with the sweet taste of them, with which they could scarcely be satisfied. This plant is cultivated, the author states, with great labor of the husbandmen every year. At the time of harvest they bruise it when ripe in mortars, and set by the strained juice in vessels, till it is concreted in the form of snow or of white salt. This, when scraped, they mix with bread, or rub it in water, and take it as pottage; and it is to them more wholesome and pleasing than the honey of bees. The people who were engaged in the sieges of *Albaria Marra* and *Archas*, and suffered dreadful hunger, were much refreshed thereby. Again, *JACOBUS DE VITRIACO* mentions reeds full of honey in Syria, pressed out by a screw and concreted by fire. *WILLERMUS TYRENSIS* speaks of it as being an article of export from Tyre; it seems to have at that time spread over all the Levant, and in the time of the Emperor *BARBAROSSA* it was made in Sicily, and used both solid and as a sirup. Sugar is said to have been imported into Venice as early as 991. It was brought from Sicily and Egypt—cheaper from Sicily—in the twelfth century. In 1166 *WILLIAM II.* gave a mill for grinding sugar canes to the monastery of *St. Bennet*. It travelled into Valencia, thence to Granada and Murcia. About 1420 the Portuguese took it to Madeira and Spain, and to the Canaries. Thence, says *DR. MOSLEY*, the cultivation of the sugar cane and the art of making sugar were extended by different nations of Europe to the West Indian islands and the Brazils.

In 1518 there were twenty-eight sugar works established by the Spaniards in Saint Domingo; and *HAWKINS* brought some of the sugar to England in 1563. Antwerp had exported it about the same time—1560. The English planters were realizing great wealth in Barbadoes in 1650, although the Portuguese supplied the most of Europe then with Brazil sugars.

The name sugar is used in the arts to denote certain substances in the vegetal and animal kingdoms, whose chief characteristics are a sweet taste and the power of undergoing, either directly or indirectly, vinous fermentation, that is, of splitting up under the influence of yeast almost wholly into carbonic acid and alcohol. Four principal kinds of sugar are known, namely, *cane-sugar*, so called from the fact that its chief source is the sugar cane, though it is found in large quantities in other plants, such as the stalks of maize or indian corn, the maple, birch, palm, the beet-root, carrot, turnip, and in a large number of

tropical fruits; *fruit sugar* is that to which acidulous fruits owe their sweetness, and hence its designation; it does not crystallize, and exists in large quantities in treacle. The third variety is called *grape* or *starch* sugar, owing to its being found in ripe fruit, such as dried raisins, figs, and the like, or from the fact that it may be produced in quantities from starch; and the fourth kind, called *milk sugar*, is exclusively found in the lacteal fluid of animals.

A remarkable feature in all these varieties of sugar is, that two of the three elements of which they are composed, namely, hydrogen and oxygen, are so proportioned as to constitute water, or, in other words, that they contain the same number of equivalents of these elements. This fact has led to sugars being designated *hydrates of carbon*; but from such terms it is not to be understood that the hydrogen and oxygen really exist as water, but rather that their combination, in the proportion in which they are found in the sugar admits of the expression. The composition of the different kinds of sugar varies only in the elements of one or more equivalents of water; to which fact may be attributed the readiness with which one species is changed into another, merely by the assimilation of that liquid. This feature in the composition of sugars extends to other substances not possessing the same properties, but readily convertible into particular kinds by certain chemical operations, such as the several starches, dextrin, inulin, gum, and several others. The following tabular view of the chemical composition of the sugars and a few of the above mentioned substances will at once exhibit the great analogy in composition between the two classes of bodies:—

Name	Composition
Cane sugar, or sucrose,	$C_{24} H_{22} O_{22} = C_{12} H_{11} O_{11}$
Fruit sugar, or fructose,	$C_{12} H_{12} O_{12} = C_{12} H_{12} O_{12}$
Starch sugar, or glucose,	$C_{12} H_{12} O_{12}, 2 H_2O = C_{12} H_{14} O_{14}$
Milk sugar, or lactose,	$C_{21} H_{10} O_{10}, 5 H_2O = C_{12} H_{12} O_{12} \times 2$
Manna sugar, or mellitose,	$C_{24} H_{24} O_{24}, 4 H_2O = C_{14} H_{14} O_{14} \times 2$
Starch and gum group.	
Starch,	$C_{12} H_{10} O_{10} = C_{12} H_{10} O_{10}$
Dextrin,	$C_{12} H_{10} O_{10} = C_{12} H_{10} O_{10}$
Inulin,	$C_{24} H_{21} O_{21} = C_{12} H_{10} O_{10} \times 2 + H_2O$
Gum,	$C_{12} H_{11} O_{11} = C_{12} H_{11} O_{11}$
Cellulose,	$C_{12} H_{10} O_{10}$

From a comparison of the formulas in the foregoing table, it will be observed that the amount of carbon in the several varieties remains the same, but that the elements of water present slightly vary, and to these their distinct and diverse properties is to be attributed.

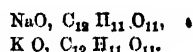
CANE-SUGAR.—*Common sugar* is manufactured chiefly from the sugar cane, but large quantities are prepared also from the sap of the maple tree and from beet-root.

Preparation.—To make pure cane-sugar the same course of operations should be followed as will be described in preparing and refining sugar, each being executed with greater care and attention; hence it will be needless to detail the process here.

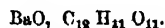
Properties.—Cane-sugar when pure, as in the finest lump, has a glistening white appearance, resulting from the multifarious reflections and refractions of light from the numerous congeries of small crystals composing it. When a very concentrated solution of this substance is left to crystallize spontaneously, it forms rhomboidal prisms with dihedral summits of considerable dimensions, especially if the nuclei be transferred repeatedly to concentrated menstrua. Thus crystallized it forms the sugar candy of the shops, and appears transparent. According to PLAYFAIR and JOULE its specific gravity is 1.594. It is soluble in about one-third of its weight of cold, and in all proportions in boiling water, forming in either case transparent colorless sirups. A solution saturated with sugar at 212° deposits a part in crystals—the candy already mentioned—on cooling. If the temperature at which the saturation is effected be raised to 230°, the whole forms a concrete granular mass when allowed to cool. This is not the case when the sirup is rapidly boiled down to the same density; for then it congeals on a cold surface in a transparent amorphous mass, which on exposure becomes opaque, owing to a fibrous crystallization radiating from the surface inwardly. In this state it is ordinarily called *barley sugar*, the change from the crystalline state being due to a dimorphism caused by the heat, analogous to that which sulphur exhibits under almost similar circumstances. Continuous boiling of a weaker sirup has a like effect. The same change, from the crystallizable to the noncrystallizable modification is effected in the cold by the prolonged contact of dilute mineral acids. Noncrystallizable cane-sugar has the composition $C_{12} H_{22} O_{11} \cdot 110$. It is gradually converted by long-continued contact with water, especially in the presence of acids, without undergoing any chemical change, into glucose or grape-sugar— $C_6 H_{12} O_6 \cdot 2 H_2O$ —a substance which crystallizes in acicular tufts. Dilute alcohol of specific gravity 0.830 takes up about a quarter of its weight of sugar. Absolute alcohol dissolves a small quantity of it at the boiling point, but deposits it again on cooling. When the crystals of candied sugar are broken, a slight phosphorescence is discernible, and a similar phenomenon is produced on rubbing two pieces of lump sugar together. Heated to 212°, no further effect is produced on crystallized cane-sugar than the expulsion of the mechanical moisture contained in its interstices. At 320° it melts; and though not decomposed, still, as PROUT remarks, several of its characteristics are destroyed. Between 320° and 350° the liquid mass becomes transparent on cooling, though, from circumstances such as those mentioned in reference to barley sugar, the transparency is destroyed after some time. At 410° it changes to an orange-yellow, afterwards to a reddish-brown hue; and if this heat be maintained, it is converted into a new acid compound of a brownish color very soluble in water—*caramel*—with the loss of three equivalents of water. If the heat be further increased, complete decomposition takes place, with evolution of inflammable gases mixed with carbonic acid, heterogeneous oils, and acetic acid; and a carbonaceous residue, forming about

a quarter of the weight of the original substance, remains.

Cane-sugar combines directly with the oxides of the alkalies and of the alkaline earths, forming with them sugarates—improperly called sometimes saccharates; and also with certain salts, particularly with chloride of sodium. The potassa and soda compounds, which are both unstable and indefinite, are obtained as sirupy liquids on adding a strong aqueous solution of the alkali to a solution of sugar in alcohol. Their compositions are—

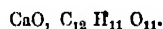


Sugarate of baryta is formed by dissolving one part of caustic baryta in three parts of hot water, and adding the solution to a sirup containing two parts of sugar and four parts of water. A mass of crystals is thus obtained resembling boracic acid, and having the composition—



Sugarate of baryta is difficultly soluble in water, and is decomposed by almost all acids into the corresponding baryta, salt and sugar. Even the carbonic acid of the air effects this change.

There appear to be three sugarates of lime, of which however the most definite and important has the composition—

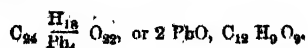


This is formed on adding milk of lime to sirup, in the proportion of two parts by weight of lime to thirteen of sugar. After filtration the sugarate of lime is precipitated by alcohol. On drying, this body appears frangible and resinous, and is very soluble in water. This compound has the rare property of being precipitated from its aqueous solution by heat, and of redissolving as it cools. The amount of lime which a sirup takes up is less according as the density of the sirup is greater. The following table constructed by PELIGOT shows this relation—

Quantity of sugar dissolved in 100 parts of water.	Density of sirup	Density of sirup when saturated with lime	100 parts of residue dried at 120° contain	
			Lime.	Sugar.
40.0	1.122	1.179	21.0	79.0
37.5	1.116	1.175	20.8	79.2
35.0	1.110	1.166	20.5	79.5
32.5	1.103	1.159	20.3	79.7
30.0	1.096	1.148	20.1	79.9
27.5	1.089	1.139	19.9	80.1
25.0	1.082	1.128	19.8	80.2
22.5	1.075	1.116	19.3	80.7
20.0	1.068	1.104	18.8	81.2
17.5	1.060	1.092	18.7	81.3
15.0	1.052	1.080	18.5	81.5
12.5	1.044	1.067	18.3	81.7
10.0	1.036	1.053	18.1	81.9
7.5	1.027	1.040	16.9	83.1
5.0	1.018	1.026	15.3	84.7
2.5	1.009	1.014	13.8	86.2

The hydrated oxide of copper is dissolved by a mixture of sugar and sugarate of lime, an amorphous double sugarate of lime and copper being formed. The sugarate of lead is not strictly an analogue of the previously described metallic compounds of sugar, which are formed by the direct union of the sugar with the metallic oxide. Sugarate of lead is sugar in

which four atoms of hydrogen are replaced by four atoms of lead—



It is produced as a gelatinous precipitate on mixing an ammoniacal solution of acetate of lead with a solution of sugar. After washing with cold it is dissolved in hot water, and allowed to stand closed from the air. The compound gradually separates out as white crystals. Massicot also gradually combines with sugar, forming the same compound, water being liberated at the same time.

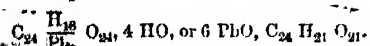
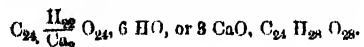
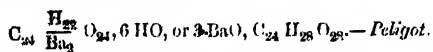
The chloride of sodium likewise combines directly with cane-sugar. If four parts by weight of sugar and one part of chloride of sodium be dissolved together in water, and allowed to evaporate spontaneously, the excess of sugar first crystallizes out; the mother-liquor, on further evaporation, deposits crystals which deliquesce in moist air, of the composition, according to GERHARDT, of—



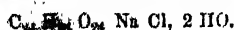
GLUCOSE, or grape-sugar, occurs in raisins, currants, and other dried ripe fruits, and in flowers. It occurs also in honey and in the urine of patients affected with diabetes, accompanying in all the above cases non-crystallizable cane-sugar. It is found also in the blood, the bile, and in eggs. Both starch and cellulose are converted into glucose by digestion with dilute sulphuric acid. The substance which appears near the germinating point at the time of germination of the cereals, called diastase, or in its crude and impure form, yeast or barm, has also the power of transforming starch into grape-sugar, for there is no evidence to show that the substance which changes starch to glucose, is other than that which changes glucose into alcohol and carbonic acid.

Aqueous alcohol dissolves all these kinds of sugar, cane-sugar, grape-sugar, and noncrystallizable sugar, in proportions greater according to the degree of dilution of the alcohol. Absolute alcohol dissolves the non-crystallizable sugar alone. This behavior is made the basis of a method of assaying sugars, as will be shown further on.

For further particulars concerning the properties and composition of this substance, see article STARCH—sub-heading *Glucose*—page 962. Glucose, like *sucrose* or cane sugar, combines with the metallic oxides to form the following glucosates—



combines with chloride of sodium forming—



It forms with sulphuric acid a copulated acid salts are both unstable and incompletely examined. With nitric acid a detonating compound is produced. Mannite forms with nitric acid a similar detonating body.

MANNITE— $C_{12} H_{14} O_{12}$ —called also the sugar of mushrooms, is chiefly extracted from manna, an exudation from the *Fraxinus rotundifolia*; it is also found in celery, dog's tooth, fennel, *et cetera*, and in algae. Mannite is one of the products of the fermentation of starch and glucose; it is produced in the transformation of starch into glucose by dilute sulphuric acid. It is readily obtained from manna by boiling it with strong alcohol; on filtering and allowing the filtrate to cool, it crystallizes out, and is purified by recrystallization from alcohol. Mannite does not readily ferment. Owing to this, it may be freed from the other sugars by submitting the liquid which contains them all to fermentation, and extracting the mannite from the unfermented residue. It is supposed that the gradual loss of sweetness effected by time on wine is chiefly due to the slow transformation which the mannite they retained after the first fermentation undergoes. Direct experiments have shown that mannite does suffer such a fermentation.

Sugar of Milk— $C_{12} H_{20} O_{20}, 2 HQ$ —otherwise called lactine or lactose, occurs in the milk of the mammiferæ, from which it is extracted by precipitating the caseum by a dilute acid, filtering, and evaporating to dryness.

Sorbine— $C_{24} H_{21} O_{24}$ —is found in a few plants.

Mosite— $C_{24} H_{24} O_{24}, 4 HO$ —occurs in the juice of flesh, it is very soluble in water; insoluble in alcohol and ether; at 212° it loses four atoms of water.

Cane-sugar, both crystallizable and noncrystallizable, and glucose, are all capable of alcoholic fermentation. But the action of the ferment is, in the first place, to transform both the former kinds of sugar into glucose or grape-sugar.—See ALCOHOL.

Testing or Estimation of Sugar.—If a watery solution contains only one of the three kinds of sugar—namely, cane-sugar, crystallizable; cane-sugar, non-crystallizable; or grape sugar, glucose; the amount of sugar may be determined from the specific gravity of the sirup. In all cases the density of the sirup is increased by an increased quantity of saccharine matter.

The following table from Dr. URE's Dictionary shows the specific gravity at 60° of solutions of crystallizable cane-sugar containing various amounts of sugar in one hundred parts by weight of the sirup:—

Sugar in one hundred parts by weight.	Specific gravity at 60°
66.666	1.3260
50.000	1.2310
40.000	1.1777
33.333	1.1400
31.250	1.1340
29.412	1.1250
26.316	1.1110
25.000	1.1045
21.740	1.0905
20.000	1.0820
16.666	1.0685
12.500	1.0600
10.000	1.0395

The subjoined more extended table has been constructed by PAYEN for a similar purpose. It shows the density at 59° of sirups formed by dissolving one hundred parts by weight of sugar in different quantities of water. The values differ somewhat widely from those given by Dr. URE:—

KUHLMANN believes that the free alkaline salts are hurtful, but has found it impossible to remove them by means of strong acids, or by sulphate of magnesia, sulphate of ammonia, or chloride of ammonium. He prefers phosphate of ammonia.

This process—one cannot speak for the phosphate of ammonia, but only for the carbonic acid—is a good deal used in France.

MAUMENÉ says that if lime is added in quantity sufficient to form three of lime and one of sugar— $3 \text{ CaO C}_{12} \text{ H}_{22} \text{ O}_{11}$ —the sugar is preserved, and nitrogenous matter falls with the lime. However this may be, if boiled with the lime the color is rapidly deteriorated.

Precipitation.—Attempts have been made to precipitate sugar from its solutions. DUBRUNFAUT and R. DE MASSY have a process depending on the union of sugar with baryta. Caustic baryta is added to the sugar till it is all thrown down. A pure compound of baryta and sugar falls, and this is decomposed by carbonic acid. It is not at all proved that all the sugar can be thrown down in this way; it is said only to be done at a boiling heat. NICKLÉ says it cannot be done with uncrystallizable sugar.—See further in accounts of *Patents*.

USES, PHYSIOLOGICAL EFFECTS, AND IMPURITIES.—Sugar exists in the juices of many plants, and is in part the food of many animals. As an article of food it has highly fattening properties, and as such it must be considered as serving mainly for the production of warmth in the body. Animals which eat it appear sleek and comfortable, and it tends to promote digestion. At the same time there are many persons who cannot use it as food to any great extent, on account of its inclination to produce acidity. The negroes, and even whites, who suck the sugar cane are not found to be troubled with these symptoms, whilst the teeth of the negro never suffer from the constant use of the sweetest liquids. Such, however, is not the case in England, where a great amount of sugar is found to be hurtful to the teeth. It is perhaps scarcely correct to say this of sugar in the diet, as it is not well known that the same effects would be produced by sugar used in abundance—in pies, for example—as would be produced by sugar taken alone and long retained in the mouth. Persons engaged in sugar works are in the habit of eating sugar very frequently. With some it is a part of their duty, as the value is to some extent measured by the taste; but whether as a duty or a pleasure, such persons are almost invariably doomed to lose their teeth at an early period. It may be said that sugars, until dried or thoroughly crystallized, have a certain amount of acidity in them; but this is in general too small to stand as a reason: much more acid is taken in other species of food. There can be no doubt that sugar in large quantities peculiarly affects the digestive organs, and causes also a distinct taste, other than sugar, to be perceptible some time. The cause may be that as an article of food it does not associate well in large quantities with the food used in this country. But, again, its valuable qualities are many, and the amount fitted for individuals must be found by experience.

The excessive use of sugar, that is, to the extent with a healthy man, of about a pound per day, produces effects not apparently much studied. One effect is a tendency to giddiness, without any observed additional inconvenience. It is possible that this may arise from the large amount of carbonic acid generated during its decomposition, causing at the same time frequent eructations.

When the throat is irritated, a solution of sugar slowly flowing over the surface prevents irritation and allays coughing. Sugar and treacle are valuable for covering burns, acting chiefly, as Mr. CROMPTON of Manchester believes, as non-conductors of heat. It is sometimes used in a powdered state for ulcers or rather proud flesh, and for specks on the cornea. It has a considerable power of reducing metallic oxides, and has been used as an antidote for poisoning by metallic salts, such as those of copper; mercury, silver, gold, and lead may be included; but this action has been referred more to its physical than to its chemical properties. It is highly antiseptic, no doubt, because it covers from the atmosphere. It is much used in pharmacy for imparting flavor to bodies, and to conceal taste. It is also found useful for giving form and consistence to some medical substances. It is employed as a medium of bulk to convey smaller substances, as in opium, lozenges, *et cetera*, and notably so by the homœopaths, whose medicines may sometimes be distinguished from sugar. Many animals delight in it. Horses put their noses into the sugar bags, and even suck them, whilst the fowls fight for the fallen pieces.

Sugar is also employed for fermentation. Indeed, properly speaking, it is the only thing used for fermentation; but sugar from the cane, and still more the less crystallizable portion, is now considerably used. It has been employed for the purpose of making oxalic acid by oxidation with nitric acid; but starch or cheaper substances are more commonly employed. Enormous quantities are used in preserving fruits. Preserved fruits are becoming daily more and more accessible and more used. Formerly fruit was preserved only by such careful and well-to-do housewives as could spend some considerable time and money on the luxury. Now the conservation forms a branch of industry or manufacture. Marmalade and preserved oranges are sent from Scotland in great quantities, and are everywhere prepared. Preserved fruit is also sent from various parts of Europe, especially the shores of the Mediterranean, and it has begun to appear at our dessert tables after arriving from the East and the West Indies. England, as usual, takes up this manufacture with great vigor. One house made a small experiment last year with thirty tons of preserved plums, and finding it successful made next year a hundred tons. The preserves were of an excellent kind, and cheaper than those made by the usual methods in smaller quantities.

The amount of sugar used in the form called sweetmeats, comfits, and bonbons is very great, and more so on the Continent, according to accounts, than here. At the same time, although one finds in France, Germany, and Italy some very handsome confectionery shops, it strikes the Editor that the amount of comfits in

them is very small, and the variety very limited. The sugar may be pure and unadulterated with arsenic and sulphate of lime, or any other noxious or poisonous substance; but the shops seem to depend a good deal on their sale of beverages, and in some places on their restricted number. No country offers such great varieties of excellent sugar sweetmeats as England, or in such rich diversity. In China the variety is said to be very great. The only fault in England is that there exist so many qualities to suit the purses of every man, rich and poor. The inferior qualities are mixed with flour. This, of course, diminishes the sweetness. This would be a small evil, if the makers did not sometimes use instead of flour sulphate of lime or plaster of Paris. Even this, however, is innocent in comparison to the coloring matters used at times. Sweetmeats are colored by ignorant people with common paints of any kind that come in the way. These are painted roughly on the sugar. Some of them contain copper, some arsenic and copper, and some lead. Several cases of death have occurred from the use of such substances; and there can be no doubt of the propriety of a surveillance over the manufacture or sale of articles liable to be so abused. The best confectioners use only innocuous colors, and these vegetal.

The unfiltered sugar, or Muscovado, as it comes from the Colonies, contains many impurities, and should never be used. Many peculiar species of beetles are found in it. One especially infests abundantly all sugar-houses. But the *acarus sacchari* is the animal that, of all others, is the most to be avoided; it is not found in filtered sugar. It is an animal somewhat like an itch insect, and a drawing would not be pleasant in an article on sugar. The grocers' itch is in all probability produced by the handling of Muscovado sugar, and the attacks of this insect. Dr. HASSALL advises the use of refined sugar only. The Editor is able to state that, in Lancashire at least, purified or filtered sugars, of various shades of color, are everywhere to be had, and they are as free from insects as the purest white kumps.

Sugar itself for domestic purposes is not now adulterated, or very rarely. There was a time when sand was used to adulterate the brown qualities; but such a practice would not now be tolerated for a moment. A very ingenious adulteration came into vogue for a while; but the Editor believes it is not resorted to now. It was the custom of using starch, or starch made into gum. When this is used in tea or coffee it is not readily distinguished from true sugar. If starch is employed it is readily found by dissolving the sugar in cold water, in which the starch is not soluble. If British gum be used it is less easily detected; it has small granules, not hard and crystalline like those of sugar, and is soluble in cold water. It also becomes gummy in drying, instead of becoming sirupy, and then crystalline like sugar. This adulteration cannot be made with pure white sugars. A microscope assisted by an ordinary good taste is perhaps the best guide to its discovery. The most general use of sugar is for sweetening tea, coffee, and chocolate; but it is also largely used in sweetening mixtures of strong drink, as well as in numberless

articles of cookery. Its abundant introduction into Europe has changed the whole system of cooking and must have largely assisted in rendering food pleasant in an age when the arts of peace have somewhat taken away the violence of appetite which is connected with rude times, and is satisfied more with quantity than quality. For the poor especially is this remarkably true.

A LIST OF SOME OF THE LATER MORE INTERESTING AND CURIOUS INVENTIONS RELATING TO SUGAR, WITH REMARKS:—

1845.—JAMES JOHNSTON patents an ingenious plan of emptying a vacuum pan without destroying the vacuum by a pipe twenty-five feet long. He also has the sugar running down an inclined plane whilst in the vacuum.

FREDRICK GYE presses sugar into suitable forms for use.

1846.—RICHARD WRIGHT patents exposure to hydraulic pressure and steam.

1847.—JAMES JOHNSTON patents polygon shaped sugar moulds, cast-iron crystallizing pots coated with tin, zinc, or enamel. The latter would be good if the enamel did not break off into the sugar.

H. K. CLAYPOLE.—Saving fuel with two generators like locomotive boilers, heated by a fire that first passes over three open boilers. A current of high pressure steam to make a draught. A hot iron tube heated by steam in the clarifying boiler. A canal in the tea-chest for running out sugar. Galvanized iron coolers. These are for the Colonies.

JOHN SCOFFERN.—Combined use of lead and sulphurous acid as separately described.

1848.—J. A. STEINKAMP patents the use of cotton in small pieces of one-eighth to one-fourth of an inch for clearing sugar.

1849.—JOHN OXLAND patents acetate of alumina boiled with sugar at 220° till the acid is removed. The alumina remaining is removed by tannin and a little carbonate of lime.

REECE and PRICE patent hyposulphites with alumina or acetate, hyposulphite of alumina, and various hyposulphites and sulphides of magnesium to precipitate lead. Also hyposulphites and sulphurous acid to remove the sulphide of hydrogen which has been used for removing lead. The bicarbonate of lime for defecation and many other things.

A. V. NEWTON.—Bones dissolved in sulphurous acid for completely extracting the crystallizable sugar. Other antiseptics, as mustard, creosote, horseradish, nitrous acid gas, with or without salts of iron or other salts. Tannin, lampblack saturated with creosote, products of the distillation of certain albuminous matter, tars, wood essence of turpentine, aldehyde, and analogous bodies, chlorine combined with oxygen. Separating ninety-seven per cent. of pure sugar by baryta, and decomposing by carbonic acid or sulphurous. Oxide of strontium, it is said, requires a long time; oxide of lead does it imperfectly. The process gives fifty to sixty parts of hydrate of baryta to one hundred of sugar. Still the sugarate obtained contains fifty per cent. sugar, twenty-two baryta, and twenty-eight water. It is decomposed by a solution of twenty-five quarts of water and twenty-eight pounds of sulphuric acid. It may be

washed till the solution has the strength of 23° to 31° Twaddell. If lime is used, twenty-eight per cent. is taken. The sugarate is filtered out in TAYLOR'S filter, or in presses warmed to 100°; it contains five equivalents of base to one of saccharic acid.

The baryta does not offer to be cheaper than animal charcoal, and baryta, at least as a soluble salt, is no less dangerous than lead, whilst it is not so easily detected. Several patents have been taken for removing the baryta, but on this point, the last traces excepted, no difficulty has been found.

C. W. FINZELL—Patent to introduce steam to clear the sieve of the centrifugal machine.

1850.—JOHN SCOFFERN makes a valve of elastic material over a perforated tube.

GEORGE GLYNNE grinds sugar with litharge, and makes a saccharide of lead.

Sugar is a very tender substance chemically. It is easily destroyed. It also readily dissolves many substances. As little of any substance should be added as possible, and as little heat should be given and as little motion.

D. T. SHEARS makes loaf sugar at once on boiling down the juice; purifies sugar by alkaline liquids and sulphurous acid gas; uses also lime and a West Indian plant called *wassama*. Puts a *rouser* in the vacuum pan for stirring round.

HERMAN SCHRODER—a combination of revolving discs on pipes heated by steam to evaporate the sugar.

1851.—R. and J. OXLAND.—When acetate of lime is used, remove by superphosphate of lime or lime. Aluminate of lime to defecate, or phosphate of alumina.

R. A. BROOMAN—Centrifugal apparatus in a vacuum pan; centrifugal drum for evaporation; centrifugal apparatus for cleaning charcoal.

1852.—HENRY BESSEMER.—The claims in this patent being nineteen, are too numerous to mention, and so complicated as to require an article for themselves. It is believed that they rather tend to load a refinery with machinery. Invention will rather simplify the machines, or altogether dispense with some of them; but there are good and ingenious thoughts amongst those of Mr. BESSEMER worth studying, although not as yet found successful.

R. A. BROOMAN.—Endless bands for carrying the sugar to be cleansed.

ROBERT GALLOWAY.—Using plumbite of lime instead of lead.

R. W. LIENIER.—Patent for applying sulphurous acid to the pulp of beet-root or cane before boiling it, adding excess of lime. Use of vessels of wood, slate, stone, glazed metal, or earthenware for boiling juice.

WILLIAM MILLER.—For never allowing the sugar to come in contact with metals; evaporating by surfaces formed of cloth or textile fabric.

BROOMAN.—Removing excess of lime by soap.

GERD JACOB BENSEN.—Hot air passed through the sugar to dry it. Crystallized sugar placed in a vacuum pan. Crystals thus got are mixed with a clear sirup produced from refined sugar; the mixture put into moulds and stored.

In 1852 J. BRANDEIS took a patent for removing lead from sugar by animal charcoal, thus being able to use lead to purify sugar. The Editor believes that the destruction of the animal charcoal soon follows. The oxide of lead, on heating, melts in the pores. This, although possible, would be very expensive.

JOHN ASPINALL proposed lifting the sugar solution in thin layers on an endless band of wire gauze, exposing it to heated air, and drawing off the water. This has not been much used. Even thin layers of sugar may become covered with a pellicle not easily broken. HOWARD'S vacuum pan, by keeping up ebullition, allows no hard surface to prevent evaporation. This, however, may be the germ of something good not yet completed.

JAMES HADDEN YOUNG presses sugar between two unyielding surfaces, one of them perforated; he uses a vacuum. The beet-root system is a similar one, but mechanical pressure is used.

HENRY BESSEMER also proposed contact of warm air, raising the sugar in thin layers on screws or discs instead of on wire gauze, as Mr. ASPINALL. He proposed also in his patents to use wooden troughs for crystallizing, and to moisten the crystals with a deliquescent compound of sugar and chloride of sodium, or with gelatine, glucose, or molasses. He adds, also, the use of hot water instead of steam to heat sugar, and warm air below 212°, and tinned vacuum pans. Tin is too easily dissolved. What might be more useful than any of the above is the enamelled vacuum pan, if such large vessels could be covered with enamel.

GEORGE DIXON has a number of perpendicular tubes, in which is placed the sugar and heated by steam; but there is a want of exposure for evaporation. Perpendicular tubes are found to heat the sugar more equally.

JEAN BAPTISTE MOINIER allows the sirup or liquid to fall over spheres, thus obtaining surface, and he allows it to descend from amongst the spheres, and exposed to warm air.

1853.—WILLIAM PIDDING patents hydrate of alumina, or silica, or a mixture incorporated with a fatty acid, and adds a little oxide of iron. He seems to wish to include the impurities of the sugar in a kind of fatty salt or soap. This answers for some liquids, but the iron will not improve sugar.

FRANK CLARK HILLS removes the lead from sugar by filtering through sawdust, or by dissolving it out with nitric or acetic acid. Animal charcoal much treated with acid soon loses its texture.

LORD HOWARD DE WALDEN cleanses crystals by hot air and steam. This is, in fact, bleaching with the atmosphere. Air bleaches many substances, but the Editor has not heard if it has been found to act favorably on sugar.

CONRAD W. FINZELL.—Defecation in vacuo. Not yet proved to general satisfaction to be of any benefit.

MANIFOLD, LOWNDES, and JORDAN—Reducing the cane to sawdust, then dissolving the sugar out by steam. This does not seem the right direction, as the great loss is in reality in the juice; it is not left in the cane.

JAMES MAGELSTON—Atmospheric pressure to remove crystals from sugar. This is in fact equal to a vacuum.

ROBERT GALLOWAY—Removing lead by tannic, gallic, and pectic acids, or the soda and potassa compounds.

JOHN and J. E. A. GWYNNE dry beet on an endless band, in one heated cylinder after another.

JOHN THOMAS WAY—Soluble silica to remove the excess of lime in defecation; filtering through a bed of Surrey silica or sand. This would add another operation, as it is supposed it would still require to be passed through the bag filters.

EDWARD BEANS puts the beating tubes into his vacuum pans vertically, and filters through a false bottom covered with sand, powdered flint, or road sweepings.

1854.—**CHARLES H. COLLETTE** proposed to defecate with lime and superphosphate of lime.

JOSEPH BOUR evaporates by a series of hollow vessels revolving in sirup and internally heated by steam; very much used, especially in the Colonies.

JAMES WRIGHT makes a centrifugal machine, where the outer case revolves with the inner, and a partial vacuum is formed to help the drainage of the liquid without the air-pump.

JOSEPH NASH adds an air-pump to his charcoal filters; fills the centrifugal machine without stopping.

W. A. ARCHIBALD consolidates sugar by exposing to cold air and agitation.

D. T. SHEARS—Another plan for filling and emptying the centrifugal machine without stopping.

PIERRE ANDRÉ DECOSTER has a patent for cutting up the canes; he then presses and mashes by centrifugal power.

L. WRAY wished to take a patent for making sugar from *Holcus saccharatus*, called *impee* on the coast of Africa. Refused.

1855.—**R. A. BROOMAN**.—A filter of cotton or other fibre between two perforated plates or frames.

JAMES STEELE says that the pin at the apex of the sugar mould is now inserted to make an outlet for the drainage. He inserts it at first, and draws it out when it is desired. A cavity is thus left which assists in drainage. By the insertion of a pin too large a hole is made.

There are many patents for the mode of cutting up sugar into lumps.

JOHN ASPINALL drives the sugar in at the apex of the cone, burning it out at the top.

C. W. FINZELL's patent for the use of **NEEDHAM** and **KITE's** apparatus in the filtering of sugar. It is the combination of grooved plates or planks, with filtering cloth, which is laid between two.

ALEXANDER W. ANDERSON precipitates sulphate of copper by tin, and obtains sulphate of tin for sugar refining; then precipitates tin by lime. Removes tin from the sugar at last by animal charcoal.

GARTON and PARSONS.—To treat sugar for distilling they add sulphuric acid, and keep the liquid at 140° for five days, then remove by lime.

STATISTICS OF THE UNITED KINGDOM.—The following, from Messrs. REID's circular, of Liverpool, with alterations, will give some interesting details relating to the United Kingdom:—

Sugar being an article of luxury rather than a necessary of life, the extent of its consumption is affected by the condition of the people as well as by market value, and any increase from the first of these causes is a satisfactory indication of prosperity. Reverting to the early years of the present century, one finds that a long continuation of high prices in addition to periodical privations among the laboring classes gradually reduced the average consumption in the United Kingdom from twenty-two pounds per head in 1801 to sixteen pounds in 1844. A combination of favorable circumstances then arose to cause a reaction; the duties were greatly reduced; production increased; prices ruled low; and an enormous influx of gold commenced pouring into the country, thereby so largely adding to the means of procuring extra comforts and luxuries, that the average consumption per head more than doubled during the last fifteen years.

CONSUMPTION AND IMPORTS.—The following statistical table, made up as far as possible from official returns, will more particularly show the changes which have taken place. The figures for the present year are only approximate, as the return had not been made out when the tables were calculated. The prices and duties quoted are for West Indian Muscovado:—

Years.	Population of United Kingdom	Consumption of Sugar.		Prices and Rates of Duty.			Duties paid on all Descriptions	Per Head
		Total Tons	Lbs per Head.	Quotations Average Price.	Rate of Duty	Total per Cwt.		
1801	16,371,554	159,916	22	50s. 5d.	20s. 0d.	79s. 5d.	£3,066,163	3s. 9d.
1811	18,548,476	187,092	23	39s. 8d.	27s. 0d.	66s. 8d.	4,652,824	3s. 0d.
1821	21,302,392	170,612	18	33s. 2d.	27s. 0d.	60s. 2d.	4,188,997	3s. 11d.
1831	24,319,811	203,812	19	23s. 8d.	24s. 0d.	47s. 8d.	4,650,606	3s. 10d.
1841	27,021,949	202,899	17	39s. 8d.	25s. 2d.	64s. 1d.	5,114,390	3s. 9d.
1851	27,721,921	328,581	26	25s. 6d.	13s. 3d.	38s. 9d.	3,979,141	2s. 10d.
1859	30,000,000	450,000	33	27s. 0d.	12s. 0d.	37s. 6d.		
					12s. 8d.	39s. 8d.	6,000,000	4s. 0d.

IMPORTS INTO THE UNITED KINGDOM FROM 1841 UP TO THE END OF 1859.

	1841.	1842.	1843.	1844.	1845.	1846.
Sugar Raw—						
Of or from British possessions	Cwts. 4,057,617	Cwts. 3,868,334	Cwts. 4,028,231	Cwts. 4,129,345	Cwts. 4,779,317	Cwts. 4,617,509
Of or from foreign countries	261	103	76	98	77,307	602,739
Total of raw sugar	4,057,878	3,868,437	4,028,307	4,129,443	4,856,624	5,220,248
Sugar refined and sugar candy	22	37	19	6	56	18,408

SUGAR—STATISTICS.

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IMPORTS INTO THE UNITED KINGDOM FROM 1841 UP TO THE END OF 1859—continued.

	1847.	1848.	1849.	1850.	1851.	1852.
Sugar raw—	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
Of or from British possessions	4,905,489	4,921,332	5,409,209	5,183,097	4,854,506	6,216,841
Of or from foreign countries	974,019	1,220,964	496,478	908,395	1,379,041	682,520
Total of raw sugar	5,779,508	6,142,296	5,905,687	6,091,492	6,233,547	6,898,867
Sugar refined and sugar candy	26,130	46,191	75,137	116,335	338,079	273,991

	1853.	1854.	1855.	1856.	1857.	1858.	1859.
Sugar raw—	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
Of or from British possessions	5,740,854	5,589,467	4,934,343	5,695,363	5,325,975	5,323,580	5,458,380
Of or from foreign countries	1,531,979	2,439,291	2,319,879	2,065,877	3,064,721	3,775,300	3,552,420
Total of raw sugar	7,272,833	8,028,758	7,254,222	7,761,240	8,390,696	9,098,880	9,010,800
Sugar refined and sugar candy	214,756	303,649	287,520	187,211	329,122	262,460	386,820

UNITED STATES.

CONSUMPTION OF FOREIGN AND DOMESTIC CANE-SUGAR, FOR THE YEAR ENDING 31ST DECEMBER IN TONS.

Year.	Foreign	Domestic.	Total.
1859 ..	239,034	192,150	431,184
1858 ..	244,758	143,634	388,492
1857 ..	241,765	39,000	280,765
1856 ..	255,292	123,468	378,760
1855 ..	192,604	185,148	377,752
1854 ..	150,854	234,444	385,298
1853 ..	200,610	172,379	372,989
1852 ..	196,558	118,659	315,217
1851 ..	181,047	107,438	288,485
1850 ..	143,045	126,421	269,466

Average increase for the ten years, 69 per cent.

Oregon and California not included.

PRODUCTION OF CANE AND MAPLE SUGAR IN THE UNITED STATES FOR 1850.

	Cane-sugar in hogsheads.	Maple-sugar in pounds.
Maine,	—	87,541
Missouri,	—	171,943
Maryland,	—	47,740
Alabama,	28	—
New Hampshire,	—	1,292,429
Vermont,	—	5,149,641
Massachusetts,	—	768,598
Connecticut,	—	37,781
New York,	—	10,310,764
New Jersey,	—	5,886
Pennsylvania,	—	3,178,373
Virginia,	—	1,223,905
North Carolina,	1	27,448
South Carolina,	150	200
Georgia,	1,273	50
Florida,	1,741	—
Mississippi,	27	—
Texas,	7,017	—
Arkansas,	—	8,825
Tennessee,	—	159,888
Ohio,	—	4,521,643
Michigan,	—	2,423,897
Indiana,	—	2,921,638
Illinois,	—	246,078
Iowa,	—	31,040
Louisiana,	262,486	—
Kentucky,	—	386,233
Wisconsin,	—	661,969
Minnesota,	—	2,950
	272,974	33,677,061

This has much increased. Louisiana produced in 1858 three hundred and sixty-two thousand two hundred and ninety-six hogsheads, at sixty-nine shillings per hogshead, and value of twenty-four millions, nine

hundred and ninety-eight thousand, four hundred and twenty-four dollars. A hogshoad is half a ton. Total Maple sugar produced in 1859 is believed to be twenty-seven thousand tons, or sixty millions four hundred and eighty thousand pounds.

The annexed extracts from the commercial review of Messrs. DE CONINCK, Brothers, and Company, furnish some interesting particulars of the statistical position of sugar in France.

The importation of foreign sugar into that country rose in 1859 to eighty-two thousand tons against forty-five thousand tons in 1858, and sixty-five thousand tons in 1857.

From the Colonies, France received last year five thousand tons more than in 1858; while the manufacture of indigenous or beet-root sugar produced in the season 1858-9, was one hundred and thirty-two thousand tons, being twelve thousand tons in excess of the first estimates. During the last six years, the quantities received by France from her Colonies were as follows:—

113,000 tons in 1859	95,400 tons in 1856
108,000 tons in 1858	89,000 tons in 1855
92,100 tons in 1857	82,000 tons in 1854
99,500 tons in 1847.	

The sources of these supplies are subjoined:—

QUANTITIES STATED IN TONS OF 1000 KILOGRAMMES.

	Guadeloupe	Martinique	Reunion	Cayenne, &c	Total.
1859 ..	24,400	27,900	58,800	1100	113,000
1858 ..	29,500	27,400	52,000	—	108,000
1857 ..	18,500	22,300	51,000	300	92,100
1856 ..	21,600	26,600	57,000	200	95,400
1855 ..	21,000	18,500	49,000	600	89,000
1854 ..	22,001	24,300	35,700	—	82,000

The consumption of sugar in France in 1850 is thus estimated:—

	Tons.
Sugar—Indigenons.....	120,000
" From French Colonies.....	95,000
" " ".....	60,000
Total	275,000
Deduct export of refined sugar.....	52,000
Remains for consumption in France.....	223,000

The season of 1858-59 produced of indigenous sugar—

132,000 tons against 150,000 tons { 1857-58
 1856-57
 1855-56

It is not thought that the quantity produced in the season 1859-60 will exceed that of the preceding one, *vide* *supra*, one hundred and thirty-two thousand tons.

ZOLLVEREIN CUSTOMS RECEIPTS ANNUALLY FROM 1834 TO 1857, BOTH INCLUSIVE.

Years.	Total population of the states of the Zollverein.	Gross receipts in account of export, import, and transit duties.	Average sum per head of the population, derived from custom dues, of <i>which</i> , tax on beet-root.
		Rix-dol.	Groschen. Pf.
1834 ..	23,478,120 ..	14,815,723 ..	18 11
1835 ..	23,478,120 ..	16,880,180 ..	21 7
1836 ..	25,150,216 ..	18,402,873 ..	22 0
1837 ..	25,150,898 ..	17,997,295 ..	21 6
1838 ..	25,048,970 ..	20,419,287 ..	23 6
1839 ..	26,048,970 ..	20,869,488 ..	24 0
1840 ..	26,048,091 ..	21,608,191 ..	24 11
1841 ..	27,142,116 ..	22,255,204 ..	24 7
1842 ..	27,578,730 ..	23,853,269 ..	25 9
1843 ..	27,623,815 ..	25,720,761 ..	27 11
1844 ..	28,498,136 ..	26,778,300 ..	28 2
1845 ..	28,499,565 ..	27,721,436 ..	29 4
1846 ..	28,508,436 ..	26,569,214 ..	28 3
1847 ..	29,461,381 ..	27,552,998 ..	28 3
1848 ..	29,460,704 ..	22,699,299 ..	23 6
1849 ..	29,461,628 ..	23,640,730 ..	24 7
1850 ..	29,800,003 ..	22,948,809 ..	23 8
1851 ..	29,800,063 ..	23,256,058 ..	24 11
1852 ..	29,800,063 ..	24,649,721 ..	26 6
1853 ..	30,492,792 ..	22,016,154 ..	23 10
1854 ..	32,559,173 ..	23,157,407 ..	24 9
1855 ..	32,559,164 ..	26,323,372 ..	27 9
1856 ..	32,721,341 ..	26,156,450 ..	28 0
1857 ..	32,940,780 ..	26,595,788 ..	29 5

FROM 1ST NOVEMBER, 1858, TO 31ST OCTOBER, 1859.

To Liverpool	about 3218 tons.
To the Clyde	" 2940 "
To London	" 1614 "
To West of England	" 1234 "
To Hull	" 37 "

Total..... " 8343 "

A good deal of this was re-exported, as it could not compete with Colonial.

PRICES CURRENT.

Low brown, equal to No. 7 to 8 Dutch standard—very scarce	21s 0d to 22s 6d
Light brown, equal to No. 10 to 10½ Dutch standard	23s 6d to 24s 0d
Grey and yellow, equal to No. 12 Dutch standard	25s 0d to 25s 6d
Per cwt., cost, freight and insurance to cover average.	

In Russia the consumption has nearly doubled within a few years; but even now it is only two pounds per head.

Dr. ANGUS SMITH of Manchester kindly rendered his valuable aid during the progress of this article, and for which the Editor is indebted to him.

SULPHUR—*soufre*, French; *schwefel*, German—is one of the elements of modern chemists, and was a still more important one in the theory of the alchemists.

OCCURRENCE.—It is found in nature, both in a free state and in combination with metals, as sulphides and sulphates. In the free state it occurs in volcanic regions, large quantities being imported to this country from Sicily. The native sulphur occurs both amorphous and crystallized. In the latter state it usually occurs in right rhombic octohedra, although it does not assume this shape under all conditions; it crystallizes in many

The duty is now seven and a half groschen for one hundred pounds, and brings nearly three shillings per head.

AMOUNT OF RAW BEET-ROOT USED FOR THE PRODUCTION OF SUGAR, AND AMOUNT OF DUTY RECEIVED IN THE STATES OF THE ZOLLVEREIN.

Years.	Amount of beet-root used for sugar. Cwt.	Produce of the tax in Rix-dol.
1842 to 1847	4,822,712	232,991
1847 to 1853	13,998,570	1,156,744
1853 to 1856	19,832,679	3,966,536
1856 to 1857	27,551,207	5,312,856
1857 to 1858	28,915,133	5,783,033

CONSUMPTION OF BEET-ROOT SUGAR IN THE STATES OF THE ZOLLVEREIN.

Years	Consumption of colonial sugar. Zollverein cwt.	Consumption of beet sugar. Zollverein cwt.	Total consumption of sugar. Zollverein cwt.
1844 to 1846 ..	1,278,421 ..	264,283 ..	1,542,704
1847 to 1849 ..	1,154,005 ..	646,050 ..	1,800,055
1850 to 1852 ..	739,968 ..	1,219,718 ..	1,959,678
1853 to 1855 ..	654,386 ..	1,487,452 ..	2,141,838

In 1856-57 there were two hundred and thirty-three manufacturers of beet-root sugar in the Zollverein. In 1839-40, four and four-fifths pounds per head was consumed; in 1853-55 there were six and a quarter pounds consumed.

The shipments of beet-root sugar, according to BARUCHSON and Company of Douai, to Great Britain, were little more in 1858-59 than half those of the preceding season, owing to the prices in England being at several periods below those of France. They consist as follows:—

forms, almost as varied as the methods of procuring the body in the crystallized state. Native sulphur is far from being pure, containing a considerable quantity of adhering soil and other matter, from which it is purified by different methods dependent on the purposes to which it is to be applied. Large quantities of sulphur exist in combination with metals as sulphides; of these may be mentioned the sulphides of copper, lead, iron, and zinc; these bodies, in fact, forming the ordinary ores or minerals of these metals, from which the sulphur has to be burnt off before the metal itself can be obtained. Sulphur occurs also in nature in saline combinations as sulphates of the alkalis and earths; for instance, the sulphate of soda and potassa, which are comparatively rare, and the sulphates of baryta and lime, which occur in immense quantities.

PROPERTIES.—Sulphur is a pale yellow, solid, very

brittle, becoming negatively electrical by heat or friction; it was at one time, in an earlier period of electrical history, used, when formed into globes and mounted as glass cylinders and plates are at the present day, as a source of electricity. Its specific gravity is variously stated, but most writers agree in considering it as 1.98—probably its density is dependent on the degree or stage of heat to which it has been carried while in a fused state. It is perfectly inodorous unless when rubbed, when a peculiar smell is developed. This was once supposed to arise from a hydrogen compound formed by friction; it is now ascribed rather to the production of ozone. Owing to its brittleness, as well as from conducting heat badly, it soon splits into innumerable cracks when held in the warm hand; by inclosing a stick of cast sulphur in the hand, and holding it close to the ear, this is easily detected, a continued series of very slight cracklings are heard similar to the cracklings of an electric machine when in work, only much fainter. Sulphur, though perfectly insoluble in water, is soluble in a variety of liquids, most of which are capable of dissolving a greater quantity of the body when hot than they are when cold, in consequence of which they, on cooling, deposit this excess in the shape of crystals. Oil of turpentine is capable of dissolving a considerable quantity. In fact, it has been proposed to take advantage of this property in the analysis of gunpowder; for by heating this body with turpentine in a warm state, having previously dissolved out the nitrate of potassa with water, we can dissolve out the sulphur, leaving the charcoal, which is not soluble in this menstruum, behind. Bisulphide of carbon will also dissolve a considerable quantity of sulphur, which can be again obtained in crystals by allowing the solvent to evaporate gradually. Fat oils are also capable of dissolving it. A compound called *oleum sulphuratum*, or balsam of sulphur, once figured in the Pharmacopœia of the London College, though now omitted. This was formed by dissolving sulphur in olive oil, employing a tolerably high temperature to effect the combination. Ether, petroleum, and fused paraffine, may be mentioned as solvents of sulphur.

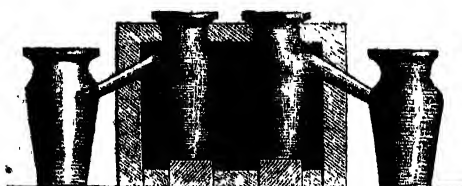
Pure sulphur exhibits some curious phenomena in connection with heat. Although perfectly solid at the ordinary temperature, it fuses at a heat little more than that of boiling water, and at a higher heat passes through various physical changes; and finally, on raising the temperature still higher, it volatilizes completely, without leaving anything behind. The following experiment is interesting, as displaying some of the peculiarities of this body:—Procure a small saucepan, and partly fill it with fragments of sulphur; place this over a gentle fire, having first put on the lid; after a while it will fuse. This takes place at a temperature of about 228°, forming a thin brownish-yellow transparent liquid. On heating still higher a very perceptible change takes place; the sulphur, instead of remaining in the very liquid state, becomes of a thick consistence, so much so that the vessel containing it may be completely inverted without fear of loss. This occurs at a temperature of between 428° and 482°. At a still higher degree the action is reversed, the melted sulphur becomes thinner and thinner until it reaches the boiling point,

when it begins to pass off as vapor. Other phenomena may be noticed by interrupting the experiment at various stages; for instance, if it be wished to obtain crystals of sulphur, it is only necessary to take the sulphur while in the first liquid stage, to pour this into a basin or other vessel with sloping sides, and there allow it to stand. In a few minutes after the top portion has solidified and formed a crust, break two holes through this crust at opposite sides of the vessel. If the basin be now inverted partially, the sulphur, which still remains in the liquid state in the interior, will run out of one hole while air rushes through the other. Let the vessel stand until cold, carefully detach the solidified mass from the containing vessel, and by means of a saw divide it into two halves. These will be found to be full of beautiful crystals of sulphur. It is possible that the first experiment may not be very successful, but a few trials will enable the operator to procure a mass of crystals, radiating into, and interlacing each other in every direction from the external crust. If the sulphur, immediately after passing, or perhaps better, while scarcely through the thick stage, be poured into water, it does not solidify and assume the ordinary yellow brittle appearance which it would do were it so treated while in the first liquid state; instead of doing so it remains in this plastic condition even when cold, bearing a stronger resemblance to caoutchouc than sulphur. In this state it is perfectly elastic, may be pulled out to a considerable length without breaking, and, in fact, does not in the remotest degree resemble sulphur. But for its color, it might be mistaken for wheat gluten, possessing the same soft elasticity as that body. It will remain in this state for some time, not resuming its ordinary aspect until after the lapse of some days.

PURIFICATION.—Sulphur occurs in commerce in several states of purity, the native sulphur being the most impure. In order that it may be more fit for the several uses to which it is applied, it is partially purified from the grosser extraneous matter, such as gravel, sand, &c. &c. This is done, according to some authors, by throwing a quantity of the crude native sulphur into a suitable iron vessel or pan, and heating this pan until fusion takes place. The sulphur when fused, of course, occupies much less space than it did in the heap, so the operator keeps filling up the pan until it is full of the fused sulphur. A high heat is not advantageous. This may be inferred from what has been said before respecting the changes which take place during the fusion of sulphur at different temperatures. For the purpose of purification the lowest heat consistent with perfect fusion is the one to be employed. The liquid sulphur is thus in its thinnest state, easily allowing the heavy particles with which it was contaminated to fall to the bottom of the pan, while any light particles rise to the top, and are skimmed off. When some time has elapsed, and the operator considers that sufficient subsidence has taken place, he proceeds to remove the upper stratum of tolerably pure sulphur, running it into moulds, from which it is removed as solid blocks of sulphur. That the method is not perfect is easily ascertained by burning a piece of ordinary commercial sulphur in a porcelain capsule. A quantity of light dust will remain,

consisting to a large extent of sulphate of lime; yet, though the purification is not absolute, it produces an article pure enough to be employed for almost every purpose required in the arts. In order to procure an almost absolutely pure article, such as is necessary for medical and a variety of other purposes, distillation, or rather sublimation, must be had recourse to. Sulphur, as has been before stated, is perfectly volatile; a ready method therefore exists of separating it from all bodies which are not so. It is said that the following apparatus—Fig. 567—is employed to effect this. A A, are two earthenware or fire-clay jars,

Fig. 567.

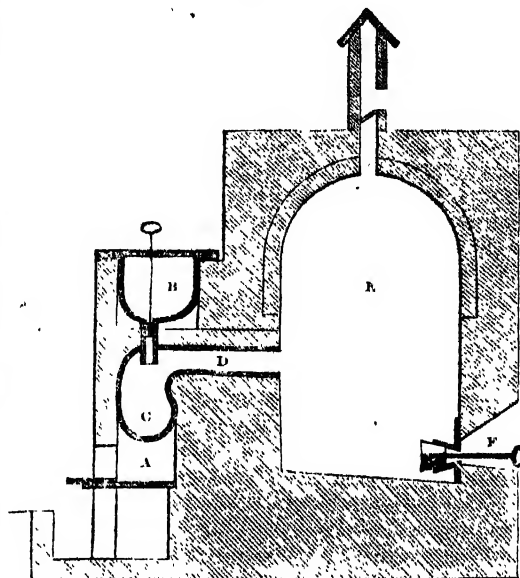


standing on a raised support of bricks. The mouths of these jars protrude slightly over the top of the furnace. This is for the purpose of readily enabling the operator to fill in the charge, and to remove the earthy residuum. A hollow tube or arm projects laterally and slightly downwards from each of the pots or retorts, which arm is thrust into another pot or vessel to receive the sublimed sulphur which condenses into it. When the subliming pot has received its charge, the lid is luted on and the furnace lighted. As they become heated, the various changes of fusion take place up to the last, when sublimation begins. The vapor then passes over into the condensing jar, and becomes solid. All the extraneous matter is left in the subliming pot, from whence it is removed prior to the introduction of another charge. This apparatus, if actually employed, could certainly furnish only a small quantity of sulphur. It is hardly possible to imagine a large gunpowder work using such an apparatus.

In 1815 a manufacturer named MICHEL, of Marseilles, devised an apparatus which, with some slight modification, is used up to the present day. The drawing—Fig. 568—represents it, and which, like the one previously described, contains a retort wherein the sulphur is converted into vapor, and a condensing chamber in which this is reconverted into solid sulphur. The apparatus, as in the drawing, consists, first, of a retort, C, beneath which is a furnace, A; this retort is filled with liquid sulphur from the reservoir, B, wherein the crude sulphur is melted by the waste heat of the furnace to facilitate its introduction to the retorts. When the retort has become sufficiently hot the sulphur begins to pass as vapor through the tube or opening, D, into the condensing chamber, E. This chamber is built entirely of brick, with a well-cemented brick floor; on its upper part a small chimney is erected; this chimney contains a sort of wooden valve or door, capable of opening outwards, to allow the expanded air to escape, and in case of explosion to allow the gases produced immediate exit. This apparatus when cold allows solid sulphur

to form at once in the shape of the ordinary commercial flowers of sulphur; the vapors immediately on coming into contact with the cold chambers are chilled, and fall as a minutely divided solid. These flowers, as they

Fig. 568.

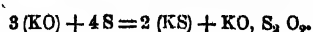


are called, are removed before the chamber gets hot, which is the case after a few days' working, the whole of the heat which the sulphur had taken up, in order to become vapor, being given out to the walls; they thus acquire so high a temperature as to fuse sulphur, therefore it can no longer become solid in contact with them, but condenses on their surface in a liquid form, and runs to the bottom, where it collects. When the operator is satisfied that sufficient has distilled over, he proceeds to remove it; this he does by means of the plug apparatus, figured at F, which is simply an iron plug with a tolerably long shank or handle, as is shown in the drawing; by pushing this plug inwards he opens the passage for the flow of the liquid sulphur, which runs into suitable moulds, to form the *stick or roll* sulphur of commerce. The residue is raked out of the retort, which is immediately charged again by removing the plug which closes the tube or passage between the vessel, B, and the retort. An apparatus better calculated for the purpose than the above, is figured in PAYEN'S *Precis de Chemie*, in which two retorts are attached to one condensing chamber; these retorts are cylindrical, and resemble to a certain extent ordinary gas retorts. A portion of the door which closes the outer end of the retort is movable, to enable the operator to rake out the debris left after distillation, the other end of the retort rises like a swan's neck before opening into the condensing chamber. Over these openings or orifices within the chamber hangs a damper or register in such a manner that it can, from the outside, be placed over them, thus cutting off all communication between the retort and the chamber.

A fusing vessel heated by the waste heat is attached, as in the drawing just given. This description of apparatus has the advantage, that by its means the operation can be rendered continuous. For instance, let one retort be called A, the other B; suppose retort, A, charged at a certain hour, and retort, B, charged some two hours later, it is certain that were they charged with an equal weight of raw material, the retort, A, would be ready for recharging two hours before retort, B. Supposing this to be the case, the damper or sliding plate is allowed to fall over the opening of retort, A, thus closing the passage between it and the condenser, and preventing the rushing back of any sulphur vapor. The cover is removed from the front opening, the impure residue raked out, after which it is again closed, the entrance into the condensing chamber is again opened, a charge of sulphur is run in from the fusing vessel, and the distillation again commences. During the whole of these operations retort, B, has been uninterruptedly at work; but eventually the same operations have to be performed in connection with it as have been detailed with respect to retort, A. Thus between the two a constant stream of sulphur vapor is being perpetually driven into the condensing chamber, the work going on almost without interruption, as the retorts never want charging simultaneously.

Sulphur thus produced is almost pure. It is true that the sublimed sulphur in powder—that is, the flowers of sulphur—contains a small quantity of sulphurous acid, which for some purposes it is necessary to remove by washing with water, but this is pretty nearly the only body it is contaminated with; the roll sulphur is free from sulphurous acid.

Sulphur occurs in commerce in another form intended expressly for medical use. When in this shape it is called *milk of sulphur*, and consists of sulphur in a very minute state of division. It is obtained in this state by dissolving ordinary roll sulphur bruised, or the flowers, in any caustic alkali, either soda, potassa, or lime; the latter used as being cheaper, and furnishing, as will be explained hereafter, a convenient adulterant. Sulphur does not dissolve in the alkaline solutions in the same manner that it does in turpentine, or any of the before-mentioned solvents. When boiled with an alkali a series of chemical compounds or salts are formed; in spiritous liquids it is a case of simple solution, exactly the same as dissolving sugar or salt in water, whereas in the other, a series of definite chemical phenomena takes place. If to a boiling solution of caustic potassa there is added as much sulphur as it will possibly take up, a liquid will be obtained containing sulphide of potassium, and hyposulphite of potassa, according to the following equation:—



In the first instance, while there is an excess of alkali, and little sulphur taken up, there is formed only sulphide of the alkaline metal and sulphite of the alkali; but this sulphite, by being boiled with an excess of sulphur, takes up another equivalent of it, being itself converted into hyposulphite. The clear liquid obtained in this way must be filtered or poured off the sediment, and excess of sulphur, and either sulphuric or hydrochloric

acid added until the liquid reddens litmus paper, when the dissolved sulphur is again precipitated in an exceedingly fine state of division. This is washed, drained, and dried at a gentle heat. It remains to examine the reaction by which the sulphur is again obtained. To do this, it will be well first to notice what the effect would be of adding acid to separate solutions of the two salts which form the mixture. If a solution of sulphide of potassium be taken, and an acid be added, a copious evolution of sulphide of hydrogen ensues, and there is obtained very little, if any, precipitated sulphur. Again, if acid is poured into a solution of hyposulphite of potassa, only a little sulphur will be separated. Hyposulphurous acid consists of sulphurous acid plus one equivalent of sulphur. Now hyposulphurous acid can only exist in combination; when set free it is instantly decomposed into sulphurous acid and sulphur— $S_2 O_2 = SO_2 + S$. This is the case on adding an acid to hyposulphites. In the first place, the alkali is detached from its combination, and this hyposulphurous acid being set free gradually resolves itself into sulphurous acid and sulphur.

It is well known that when sulphide of hydrogen and sulphurous acid are brought into contact with each other a decomposition ensues, water and sulphur being the result, as shown in the following equation:—



Thus is explained the reproduction of the whole of the sulphur employed. Hyposulphurous acid and hydrosulphuric acid, or sulphide of hydrogen, are set free in the first instance; the hyposulphurous acid splits into sulphur and sulphurous acid, the latter immediately reacts upon the sulphide of hydrogen, producing together sulphur and water. This reaction is not very complete, although it is nearly so—the more correct reaction is given under *Pentathionic Acid*. In ROYLE'S *Materia Medica* it is recommended, in order to obtain milk of sulphur, to boil one part of sublimed sulphur with two parts of slaked lime and sufficient water, and to add hydrochloric acid to the clear liquid obtained.

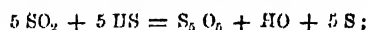
Lime is almost invariably used by the manufacturers as a solvent, but they are guilty of substituting sulphuric acid for hydrochloric as a precipitant. By so doing, instead of forming the soluble chloride of calcium, which is easily removed by washing, they form the very insoluble sulphate of lime which, mixed with the sulphur, forms the article commonly sold by druggists as milk of sulphur, and thus what should be pure sulphur is contaminated by this worse than useless sulphate of lime, often to the extent of more than fifty per cent. In one sample obtained from a druggist, and which was stated to be pure, fifty-six per cent. of sulphate of lime was found. It is useless to argue that such a sophistication is harmless; for, although not positively poisonous, the introduction into the stomach and bowels of a quantity of this insoluble matter cannot but be productive of harm. Sulphur is used in medicine as a mild purgative, and in some skin diseases. The stores of sulphur which this country possesses, in one form or another, has not been overlooked by practical scientific men.

EXTRACTION OF SULPHUR FROM ITS ORES.—The immense quantities of sulphur stored up in the shape of sulphate of lime and baryta, as well as the sulphides of iron, zinc, lead, and copper, is almost beyond calculation. There is good reason to suppose that at some future time the sulphur combined with these metals, and which at the present time is separated from them only to be thrown into the air, will be recovered in a tangible solid form, at a price low enough to compete with foreign sulphur. The attempts to do this already have been numerous. In many parts of the country iron pyrites is plentiful, and this mineral appears to have been a favorite material with inventors. It is a mixture of bisulphide and protosulphide of iron. The second equivalent of sulphur of the bisulphide is held rather loosely, so much so that a red heat, continued for some time, will drive it off, leaving one equivalent of iron combined with one of sulphur, forming the protosulphide. Here, it would appear, a process for obtaining sulphur readily is at hand; but if it be considered that the sulphur ores of this country rarely contain more than thirty per cent. of sulphur, and that, at the most, but two-thirds of this exist as bisulphide, and that only half of this latter quantity can be expelled by heating with exclusion of the air, it will at once be apparent that the process could never be rendered remunerative. Such a method is, however, pursued in some parts of the Continent, where sulphur ores are found of a much richer kind, and in which there is also a greater proportion of bisulphide, but not exactly by the same method that sulphur is purified. The process appears to be one of slow distillation of one part of the sulphur, at the sacrifice, by combustion, of the other. It is stated—KNAPP—that not more than one-fourth of the sulphur actually contained in the pyrites is obtained. This process has formed the base for several improvements. It would appear that inventors are quite aware of the benefits that would result from the discovery of a process whereby sulphur could be separated from the pyrites on the spot, even if only the saving the expense of carriage, if nothing else, of the vast quantity of iron. The following process was invented by Mr. LEE. He first converts the sulphur in the pyrites, or other mineral, into sulphurous acid, and then proceeds to recover the sulphur from this by passing it through a quantity of coke heated to bright redness. The oxygen of the sulphurous acid combines with the incandescent carbon, forming carbonic oxide, *et cetera*, while the sulphur is left in a free state, and in vapor. It passes on to a suitable condenser, in which the bulk of it is recovered in a melted shape; that which escapes melting is received into a vaulted chamber similar to the one employed in the refining of sulphur by sublimation, and in those obtained solid in the form of flowers of sulphur.

This process, or rather the apparatus, appears to be of a very complicated character. Mr. SPENCE of Manchester, in a process patented by him a few years ago, has materially simplified it, although he works on precisely the same principle. Mr. SPENCE's apparatus consists simply of an ordinary pyrites burner, such as is used in the manufacture of sulphuric

acid, to which is attached a number of condensing vaults. He charges his burner with alternate layers of charcoal and the pyrites under treatment; having first heated the brickwork of the burner up to the proper pitch. When at work, the action is very simple—the pyrites burns with production of sulphurous acid; each atom of this gas has to traverse a bed or layer of red-hot charcoal. Now, as just before stated, carbon having a greater affinity for oxygen than sulphur has, forces this sulphurous acid to yield up its oxygen, thus setting the sulphur free. The sulphur passes on with the current of gases, and is deposited in a state of powder in the condensing chambers. This plan appears to be more feasible, and better capable of working on a large scale than the one preceding.

While speaking of precipitated sulphur, it was shown how it was possible for sulphide of hydrogen and sulphurous acid gases to react upon each other, the eventual products being water and sulphur. This reaction has been taken advantage of in a process patented by Mr. DUCLOS of Swansea. He proposes to conduct into a leaden chamber, such as is used in the production of sulphuric acid, a mixture of two volumes of sulphide of hydrogen and one volume of sulphurous acid, a quantity of steam being at the same time admitted into the chamber. This, at first sight, appears to be very workable. It is easy to see that the two gases could be regulated to each other, and a constant action go on: the sulphur in a fine state of division would be deposited on the floor of the chamber, while the excess of atmospheric air, *et cetera*, would go out through proper openings at the end of it. But it unfortunately happens that only about one-half of the sulphur actually contained in the two gases is obtained. When these two gases are brought together, water being present, the results actually are water, sulphur, and pentathionic acid—an acid of sulphur with the formula S_5O_8 . Its production may be explained as follows—

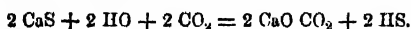


that is to say, that five equivalents of sulphurous acid and five equivalents of sulphide of hydrogen produce, by their mutual reaction, five equivalents of water, five equivalents of sulphur, which are deposited, and one equivalent of pentathionic acid. By calculation it is thus found that by this only one-half of the sulphur would be obtained in the solid state, for in the sulphurous acid there are five equivalents of sulphur, and five more in the sulphide of hydrogen; and for these ten equivalents of sulphur one recovers only five, the rest going to form the pentathionic acid, a body for which no use in the arts has yet been found. Thus, instead of burning the pyrites, or other minerals, and endeavoring to separate the sulphur from the sulphurous acid produced, it would be more economical to convert it into sulphuric acid at once.

Mr. GOSSAGE surmounted the pentathionic acid difficulty, by causing the reaction to take place at a high temperature. His process is peculiarly applicable to the reproduction of the sulphur contained in the lime compound or alkali waste thrown away by the soda manufacturers. As is well known, the whole of the sulphur used in the manufacture of the alkali finds

its way into the vat waste. Mr. Gossage proceeds to decompose this vat waste by means of carbonic acid. The action of this acid causes sulphide of hydrogen to be evolved. A portion of this sulphide of hydrogen is converted by burning into sulphurous acid, which sulphurous acid is made to react, at a high temperature, on a fresh portion of sulphide of hydrogen, when water and sulphur are produced. His apparatus consists of four distinct portions—the first for the production of the requisite carbonic acid; the second for the decomposition of the alkali waste; the third is for the decomposition of the sulphide of hydrogen; and the fourth for the collection of the sulphur produced. The apparatus for the production of the carbonic acid is an ordinary lime-kiln, with some additions to render it more fit for the special purpose to which it is to be applied. It is fed with a mixture of common coke and limestone, air being admitted for the purpose of combustion in the usual manner. The apparatus is of the continuous kind. It is fed constantly at short intervals with the above materials, the quicklime produced being removed from the bottom of the kiln at stated periods. The action of this kiln is simply the decomposition of the limestone, the carbonic acid evolved, together with that furnished by the combustion of the coke, being carried to where it is needed in the next stage for the decomposition of the vat waste.

The composition of this compound may be considered definitely settled. It seems to be tacitly allowed with DUMAS that its composition is $2 \text{CaS} + \text{CaO}$, or two equivalents of sulphide of calcium, united to one of lime; but the research of Mr. J. W. KYNASTON lately in the Editor's laboratory, has indubitably proved it to be simply a protosulphide of calcium with carbonate of lime. This substance, the composition and properties of which have been fully discussed under the article SODIUM, though insoluble in water, is capable of being decomposed by carbonic acid, especially when in a loose porous state; one equivalent of the lime compound, and three equivalents of carbonic acid producing three equivalents of carbonate of lime, and two of sulphide hydrogen, as follows:—



The apparatus employed, or proposed to be employed in the decomposition of this compound by Mr. Gossage, consists of two large chambers, or rather large columns, filled with numerous perforated floorings or stages on which the alkali waste is placed; these chambers or columns are placed side by side, and so connected together, that the carbonic acid which is admitted at the bottom of one column, emerges at the top, and is conducted by a proper passage to the bottom of the adjoining column, up which it passes, as in the previous case. The material to be operated upon is laid on the perforated floors, in a loose open manner, to facilitate the passage of the carbonic acid; this ascending from the bottom of the column, penetrates through each of these separate masses, decomposing each particle with which it comes in contact. This course it pursues until it reaches the terminal point of this portion of the apparatus, at which time the carbonic acid is supposed to have been completely absorbed, and replaced by the

liberated sulphide of hydrogen which has now to be decomposed. In order to this effect, the inventor has constructed a furnace of a rather peculiar character. This furnace has a closed ash-pit, or an ash-pit whose inlet can be closed or not, at pleasure, by means of a damper or register; the flue or passage for the gases leading from the waste decomposer is divided into two at this point, one part of the sulphide of hydrogen is drawn into this ash-pit, and so through the bars and fuel of the furnace, while the other portion is admitted immediately above the burning fuel; by this means a quantity of sulphurous acid is produced, which, in coming in contact with a fresh portion of sulphide of hydrogen at this high temperature, decomposes it, forming, as shown before, sulphur and water. This sulphur, of course, is in the state of vapor, mixed or diluted with a variety of other gases; it now remains to separate this valuable ingredient from the mass of inert and useless gases which accompany it. For this purpose an apparatus similar to the one last described is employed. This column is built of bricks or other suitable material, and is filled with coke; a cistern of water is placed on the top, by means of which, with the assistance of an apparatus for the spreading of the water in the form of rain over the whole area of the column, the coke is kept drenched with a stream of water. The vapors issuing from the furnace, consisting, as before stated, of sulphur vapor, mixed with other gases, is forced or drawn in at the bottom of this column, when, meeting with the cold wet coke, their temperature is almost instantly brought below the melting-point of sulphur, and this body is deposited in the solid state in the form of an impalpably fine powder, which mixes with the stream of water, and is finally carried out with the stream, forming with it a milky liquid, which falls into a proper cistern or reservoir, from which the sulphur is separated by deposition; from thence it is removed, and fused into a coherent mass, to fit it for the purposes of commerce. Between each of the different portions of the apparatus just described, the inventor places an ordinary draught or blower-fan, which rapidly removes the gaseous products from one portion, forcing them into the next. The various columns, *et cetera*, are of such dimensions as to insure a sufficiently quick passage for the products.

In theory this would appear to be perfection, inasmuch as we have here the recovery of the sulphur, which is the main object; and also the recovery of the lime, this body being left as carbonate after decomposition. As most alkali manufacturers are also manufacturers of bleaching powder, or chloroxide of calcium, this process offers an unfailing supply of lime; or if the recovered carbonate of lime just spoken of should not be found to answer for the soda decomposition a second time, that produced in the kiln could be used in the black-ash furnaces, instead of the limestone usually employed. It thus offers a considerable advantage if it should turn out to be as practically valuable as it is theoretically interesting.

Messrs. M'DOUGALL and RAWSON, in a patent, dated May 21, 1849, claim a process for the reproduction of sulphur from sulphide of hydrogen, from whatever source obtained. This they effect by passing it through

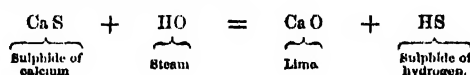
a pipe, heated to a red-heat, wherein the gas is split up into its constituent elements, sulphur and hydrogen; the sulphur is collected in any convenient manner. This process does not appear eminently practical, if the experiments of COHENWINDER be correct. He states that by passing sulphur vapor and hydrogen over or through porous bodies, kept at a red-heat, he obtained sulphide of hydrogen, exactly the reverse of this process. At any rate in a laboratory M'DOUGALL'S operation answers perfectly.

Messrs. DYAR and CHISHOLME secured a patent in 1839, for the recovery or reproduction of sulphur from sulphurous acid. It consisted in submitting the gas while at a red-heat to the action of hydrogen, which latter seized upon the oxygen, forming water and liberating sulphur. Two furnaces of proper construction were erected, side by side, one adapted to the combustion of pyrites, the other constructed in such a manner that it afforded a stream of hydrogen, mixed with carbonic oxide, obtained by passing a current of steam through or among incandescent coke. The gases were brought together at a point of junction kept sufficiently hot by the combustion of the materials themselves. At this point the decomposition took place, the sulphur vapor passing on to a proper condensing apparatus.

Amongst a most numerous array of methods for procuring sulphur, or for separating it from natural combinations, perhaps one of the most theoretically ingenious is that mentioned by PARNELL as being devised by M. THAULOW. It is for producing sulphur from the natural sulphate of lime. He proposes to reduce this to the state of sulphide of calcium, which salt he then decomposes by means of carbonic acid, obtaining by this means sulphide of hydrogen and carbonate of lime. He effects the deoxidization of the sulphate of lime, or its reduction to sulphide of calcium by mixing it, in fine powder, with coal-dust, exposing this mixture to a red heat for a sufficient length of time in a retort of clay or iron; the carbon unites with the oxygen of the sulphuric acid and lime, and becomes carbonic acid, which he reserves, or immediately uses for the decomposition of a previous charge. Carbonic acid, as stated while describing Mr. GOSSAGE'S process, is able to decompose sulphide of calcium, driving off sulphide of hydrogen. Thus M. THAULOW proposes to burn sulphide of hydrogen in lieu of sulphur for the production of sulphuric acid. There are reasons for supposing that this process can never be successfully carried out. In the first place, as PARNELL observes, if the exact quantity of carbon only necessary to combine with all the oxygen present, is added, the reduction would be extended over a great length of time, and would probably never be complete; and again, were an excess of carbon to be employed, so as to hasten the decomposition, carbonic acid would not be obtained, for carbonic acid passed over red-hot carbon would part with half its oxygen, becoming carbonic oxide—CO—a gas which could not possibly be substituted for the carbonic acid in this case. By a little addition the process can be made theoretically possible; still, the probabilities are that it will never be practically worked, unless sulphur should rise in price much higher than it is likely to do.

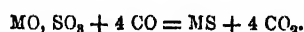
As an instance of the manner in which old and useless, or exploded inventions again arise, one may mention the re-invention or revival of this very process by OTTO KÖHSELL, who patented it for the kingdom of Hanover in 1856. The process, as detailed by this inventor, is precisely the same in every detail as that of M. THAULOW—not the main principal only, but in every minute particular it is a perfect copy.

In 1857 Mr. GOSSAGE invented, and secured by patent—dated September 12th in that year—another process for obtaining the sulphur from the sulphide of calcium of alkali waste. In the place of hydrochloric or carbonic acid, as in his method of decomposition before mentioned, he liberates the sulphur in the form of sulphide of hydrogen, by acting upon the waste with steam at a high temperature. The following equation represents the change that ensues—



The sulphide of hydrogen so obtained he applies instead of sulphur, in the production of sulphuric acid by burning with atmospheric air, so as to form sulphurous acid gas; or he obtains the sulphur itself from the sulphide of hydrogen by causing sulphurous acid to act upon it, when mutual decomposition takes place.

When carbonic oxide gas is passed over the sulphates of the alkalis or alkaline earths in a state of ignition, the salts are reduced to sulphides with the simultaneous conversion of the carbonic oxide to carbonic acid, thus—



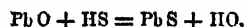
Now, as Mr. GOSSAGE has shown, if steam at a high temperature be caused to act upon the sulphides of the alkaline earths, sulphide of hydrogen is liberated. If, therefore, a mixture of steam and carbonic oxide gas be passed over the ignited alkaline, or earthy sulphates, the sulphur of the sulphate will be obtained as sulphide of hydrogen, and may afterwards be obtained in the free state. This method has been lately proposed by M. JACQUEMIN, for the production of sulphur from sulphate of lime, and also for obtaining, at the same time, soda in the caustic condition from sulphate of soda.

The author appears to think that by means of this process he will revolutionize the soda manufacture, as he anticipates the recovery of the whole of the sulphur in an available form without the production of any waste whatever. Even if this process would answer on a small scale, its success on a larger one is very doubtful. Were its success an absolute and undoubted fact, and the reaction clean and exact, it would be capable of considerable extension. The sulphur from sulphate of lime might be recovered in like manner. It would only be necessary to mix it in the manner M. THAULOW proposes to do with small coal, or other carbonaceous or reducing matter; heat to bright redness in a closed retort for some hours, until it was reduced to the state of sulphide of calcium; then to pass steam over and drive off the sulphur as sulphide of hydrogen, while lime would remain behind as

quicklime. This process, which is tacitly indicated by the author, should be much superior to that of M. THAULOW just mentioned; but it would appear that a like fate has awaited both processes; in fact, that they are each impracticable on a large scale, or, what is the same thing, they would not pay at present.

These are not the only methods which have been proposed for the recovery of sulphur from its various combinations; but they serve to show, to a certain extent, the industry of the various inventors who have turned their attention to the subject; and though success has not followed to the extent no doubt expected by the sanguine chemist, there is no reason for despair. It is still to be hoped that some one, more successful than his predecessors, may yet, in some fortunate moment, hit, either upon a yet latent reaction, or by some perhaps trifling variation of an already known mode of procedure, bring forward a simple and easily-worked process, that shall be all that could be desired, producing sulphur at a price sufficiently low to compete successfully with the imported article. Sulphur, in a state of combination, exists in this country in almost inexhaustible quantity. To separate this, and to produce it in a state of comparative purity, is what is wanted. When this is done, English manufacturers will be in a state of great independence. It scarcely need be added that by such a discovery the fortunate individual would be more than repaid for a life's industry.

COMBINATIONS OF SULPHUR.—Sulphur enters into many combinations, both simple and complex; it combines, with a few exceptions, with all the metals, forming with them proper insoluble compounds. The sulphides of the alkaline and earthy metals are soluble in water. Some sulphides are decomposed by acids, while others again are insoluble in these liquids. Of these peculiarities chemists avail themselves largely in analysis; for, by this property of forming insoluble compounds with sulphur, they are enabled to separate into classes several groups of metals, from which again, by a series of subdivisions and subclassings, they can separate individually each element. The larger groupings are made chiefly through the instrumentality of sulphide of hydrogen. This gas, when passed through a solution of metallic oxides, in many cases throws down the metal as a sulphide, the gas being decomposed. As an example: if a current of sulphide of hydrogen be passed through a solution of a salt of lead, the following reaction takes place—

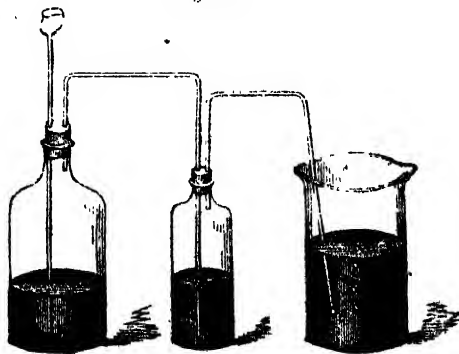


Sulphide of lead and water are the products of this decomposition. The following metals are thrown down as sulphides by sulphide of hydrogen from an acid solution—gold, platinum, mercury, silver, lead, bismuth, and copper, black; antimony, orange; arsenic, tin, and cadmium, yellow. The following metals are converted into sulphides when sulphide of hydrogen is passed through their alkaline solutions, or a slightly alkaline solution, in which their hydrated oxides are suspended—nickel, iron, and cobalt, yellow; tin, black; manganese, flesh-colored; zinc, white. Sulphur enters into the vegetal kingdom; it is found in more or less

quantity in many plants, chiefly in connection with nitrogen, with which it would appear to act in consort, at least in the organic world. In the animal kingdom it occurs pretty extensively also, and there too it is principally found in nitrogen compounds. Animal and vegetal products of the albumen and fibrin class contain it as an essential element, while its existence in the form of salt, as sulphate, *et cetera*, is still more diffused. It combines, as will be presently shown, with several proportions of oxygen, and with hydrogen in at least two proportions—the sulphide of hydrogen spoken of so repeatedly in this article when treating of the recovery of sulphur, and another body containing much more sulphur, its formula being given as H_2S_2 . This body is produced, appearing in the form of oily drops, which subside when a solution of pentasulphide of potassium is poured into dilute hydrochloric acid; it is very unstable; the greatest care and precaution cannot preserve it longer than a few weeks, even though it be sealed hermetically in a glass tube; it simply forms a link of the chain of combinations which sulphur is capable of forming.

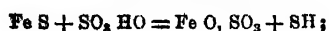
The simpler combination with hydrogen is a well known body; it is the result of many decompositions, natural and otherwise; it is permanently gaseous, possessing a most nauseous odor, easily recognized as being the characteristic of several mineral springs, such as those of Harrowgate, *et cetera*. It is a product of the decomposition of many organic bodies, is evolved by putrid bodies, and is the cause of the smell of rotten eggs, the albumen of which, as before stated, contains a quantity of sulphur, is undergoing decay, and gives off its sulphur, or a part of it, as sulphide of hydrogen. This gas is prepared by adding an acid to any soluble sulphide, such as those of the alkalis, or of the alkaline earths. The most convenient, and consequently the most general method, consists in adding dilute sulphuric acid to sulphide of iron, placed in a bottle, closed with a cork, perforated with two holes, one for the passage of a tube funnel, through which sulphuric acid can be poured; while through the other is passed a tube for the exit of the gas—Fig. 569. If a slow

Fig. 569.



and constant stream of the gas is required, large lumps of the sulphide should be employed; but if, on the contrary, a rapid stream is needed, smaller lumps should be used. When the sulphide is introduced, the cork should be put in its place, and the requisite

quantity of dilute acid poured down the funnel; if the sulphide be good, a stream of gas bubbles will immediately begin to rise, and passing through the exit tube, can be directed through any solution, or to any required point. The decomposition which produces this gas from these materials is very simple—

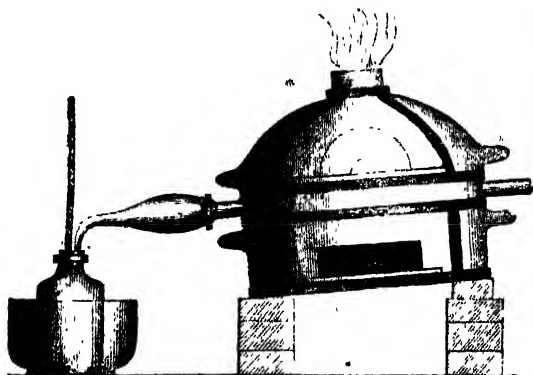


that is, one equivalent of sulphide of iron, one of sulphuric acid, and one of water, produce one equivalent of sulphide hydrogen, and one of protosulphate of iron.

The combination of sulphur with nitrogen alone is of scarcely any importance, and need not be dwelt upon.

Sulphur and Carbon.—Sulphur forms several combinations with carbon; the one most marked and of the greatest importance, inasmuch as it is used in the arts, is the bisulphide of carbon or sulphocarbonic acid— CS_2 . It is formed by passing the vapor of sulphur over or through red-hot charcoal. This is effected by filling an iron or porcelain tube placed across a furnace—Fig. 570—with fragments of charcoal. One end of this tube is connected with a condensing apparatus—**LIEBIG'S** tube will do—plentifully supplied with cold water. The other end of this tube must be capable of being closed tightly with a cork. When the tube is sufficiently hot the cork is removed, and small

Fig. 570.



pieces of sulphur are pushed through near to the charcoal. The orifice being again closed, the sulphur is converted into vapor, and in passing through the *interstices* of the *incandescent* carbon, combines with a portion, forming the body in question, which, passing on to the condensing apparatus, collects as a liquid. After sufficient time has elapsed a fresh portion of sulphur must be introduced, the operation being continued in this manner until sufficient has been prepared. This product is by no means pure, containing more or less sulphur which has escaped combination, and from which it must be freed by distillation in a glass retort placed in a water bath.

Bisulphide of carbon has a density of 1.272. It is, as obtained above, a transparent, colorless liquid, of a strong disagreeable odor. This odor is due to a foreign

body, the true smell being of a vinous or ethereal character. A considerable portion of this smell may be removed by shaking it up in a bottle with a quantity of strong sulphuric acid and bichromate of potassa. Bisulphide of carbon is a very volatile body, its boiling point being 110° . It rapidly evaporates, almost equaling sulphuric ether in this respect, diffusing its odor through the apartment. It is a very effective solvent fatty matter. Grease stains may be removed by it from paper or woven fabrics. It is only necessary to place a piece of blotting paper below the stain, and drop the bisulphide of carbon on it; it dissolves the grease, and the blotting paper receives the solution. When brushed the fabric must be exposed to the air, when the odor rapidly and perfectly disappears. Bisulphide of carbon is also a solvent of phosphorus; when a little bisulphide of carbon is warmed in a test tube and a piece of phosphorus dropped in it, it rapidly dissolves. This is a case of true solution. The phosphorus is again deposited unaltered on the evaporation of the solvent. It has been proposed to employ this solution in warfare. Shells filled with the solution were to be thrown into or on any combustible part of the enemy's premises, such as a wooden building or a ship's sails. The solvent evaporates, leaving a thin layer of phosphorus, or, in the case of a ship's sails, leaving every thread or fibre covered with a coating of phosphorus. This quickly begins to oxidize, and finally takes fire, which fire will communicate to the surrounding parts. The experiment may be performed on a small scale by wrapping a little tow round the end of a wire, and dipping this into the phosphoric solution, when, on taking it out and waving it about, the bisulphide of carbon almost instantly evaporates, and in a few seconds the tow takes fire, the phosphorus having ignited first.

Sulphur and Chlorine.—Sulphur also combines in a variety of proportions with other bodies, as well as those named. It forms combinations with phosphorus, boron, iodine, bromine, fluorine, and chlorine. One of its combinations with the latter body is used in the manufacture of caoutchouc; it is prepared by passing chlorine gas through melted sulphur, forming the dichloride of sulphur, which is found to contain also sulphur in solution. From this it must be freed by distillation, at a low temperature, and, if necessary, the rectification repeated until its boiling point is stationary at 228.2° . This chloride of sulphur has some curious properties; by means of it, a species of artificial india-rubber may be produced. To procure this body take a quantity of vegetal oil, say linseed or rape, and mix it with one-tenth its bulk of chloride of sulphur, and slightly warm the mixture; a strong reaction takes place. Hydrochloric acid is disengaged, and a mass remains, which, when washed with water, becomes white, and is as elastic as genuine caoutchouc, with precisely the same appearance. This curious body resists the action of boiling alkalis; ammonia and concentrated acids are without action on it, and it resists the solvent powers of alcohol, ether, sulphide of carbon, and oils.

Compounds of Sulphur and Oxygen.—Sulphur appears to have a great affinity for oxygen, with which it combines in many proportions, forming a series of

compounds, all of which are acids. The following are known to exist at present:—

Hyposulphurous acid.....	$S_2 O_4$
Pentathionic acid.....	$S_5 O_8$
Tetrathionic acid.....	$S_4 O_8$
Trithionic acid.....	$S_3 O_6$
Sulphurous acid.....	$S O_2$
Hyposulphuric acid.....	$S_2 O_5$
Sulphuric acid.....	$S O_3$

Of this series two members have been already noticed—hyposulphurous acid and pentathionic acid. Hyposulphurous acid cannot be obtained in the free state, as already mentioned. When set free it splits up gradually into sulphur and sulphurous acid. It is commonly met with in the form of hyposulphite of soda, a compound employed to a considerable extent by photographers, it being a solvent of certain silver salts, which are insoluble in water, such as the chloride, iodide, and bromide. Hyposulphite of soda will also dissolve sulphate of lead, and in analysis affords a ready means of separating this salt from sulphate of baryta.

Hyposulphurous acid is comparatively stable when combined with a base. The hyposulphites of the alkalies and of the alkaline earths are those most frequently occurring. They are prepared in a variety of ways, the most common methods being either by exposing an alkaline or earthy sulphide to the air, when it absorbs oxygen, forming a quantity of hyposulphites and other salts; or by boiling a sulphite of the base with sulphur. The reaction in the latter case is very simple. Take the sulphite of soda for instance. This has the formula NaO, SO_2 . Add to this one equivalent of sulphur— $NaO, SO_2 + S$; and hyposulphite of soda— $NaO, S_2 O_5$ —is produced.

The following method appears to be a favorite one for preparing the hyposulphite of soda in small quantities:—One pound of pure crystallized carbonate of soda, is dried as perfectly as possible. When powdered, this is mixed with five ounces of pure sulphur, the mixture heated in a glass or porcelain basin to the melting point of sulphur, and kept at that temperature for some time, stirring constantly in order to bring every part into contact with the air. The sulphide of sodium formed at first absorbs oxygen from the air, and is converted with feeble incandescence into hyposulphite of soda. The mass, when cold, is dissolved in water, and boiled with sulphur for some time, and the liquid evaporated to the crystallizing point. Very fine and pure crystals are obtained in this manner. If the heat be too strong, part of the sulphur is burned off, and carbonate of soda remains undecomposed. In this case a second crystallization is requisite. Hyposulphite of soda can easily be obtained by passing a current of sulphurous acid through a solution of sulphide of sodium, boiling, filtering, and evaporating to the crystallizing point.

The earthy hyposulphites, as above stated, are formed by exposing their sulphides to the air; for instance, in a solution of sulphide of calcium exposed for some time in this manner, a considerable quantity of hyposulphites form by double decomposition. The hyposulphite of soda or potassa may be formed by adding to a solution of the sulphide of calcium a solution of the carbonate of these alkalies.

Hyposulphite of soda is used to a small extent in

analysis as a reducing agent, also as a means of separating iron and alumina, dependent on the fact that hyposulphite of alumina is not stable at much above the ordinary temperature. For instance, suppose iron and alumina are both contained in a solution; to this solution is added as much hyposulphite of soda as will convert these bases into hyposulphites; this is done while cold. The solution is now heated to boiling. Hyposulphite of alumina decomposes at this temperature into sulphur, sulphurous acid, and alumina, while the iron salt being more stable remains intact. The whole is now thrown on to a filter; when the iron salt passes through, while the alumina remains on the filter; and it is washed, dried, and ignited. The iron is separated from the filtrate in the usual manner.

This reaction is used, also, to a very small extent in calico-printing. A hyposulphite of alumina is formed in the cold by adding a solution of chloride of aluminium to a solution of hyposulphite of soda. The result is a solution of chloride of sodium and hyposulphite of alumina. This is thickened in the regular manner, and printed on the fabric. The piece is then exposed to a temperature of 212° by means of steam, when the salt is decomposed, alumina being deposited on or in the cloth. This alumina so deposited dyes up with madder precisely like the alumina precipitated in the ordinary manner from the acetate.

This method does not offer any advantage over that usually followed, except in certain cases, where it is a convenient course, on account of the ordinary method being inadmissible.

The rest of these sulphur and oxygen compounds, with the exception of sulphurous and sulphuric acid, are at present useless in the arts, but are valuable in a scientific point of view.

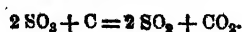
Sulphurous acid is composed of one equivalent of sulphur and two equivalents of oxygen. It is the irritating vapor or gas given off by burning sulphur. It may be prepared in a variety of ways, according to the purpose for which it is required. Two general principles may be followed, either the addition of a sufficient quantity of oxygen to sulphur, or the abstraction of oxygen from sulphuric acid.

When sulphur, as just stated, is made to burn in oxygen gas or common air, sulphurous acid is obtained. If it is desired to pass a stream of this gas through any liquid intended to absorb it, the sulphur must be burned in a close vessel or apparatus, which has a strong aspirator attached. The Woulf's bottle, or other vessel, must be placed between the vessel containing the sulphur and the aspirator, or, supposing this to be inconvenient, the sulphur may be mixed with some body containing oxygen loosely combined, and this mixture heated. A body possessing these requisite qualifications is found in peroxide of manganese. To obtain a stream

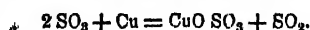
Fig. 571.



of sulphurous acid, it is recommended to make an intimate mixture of one part powdered sulphur, and seven or eight parts of black oxide of manganese. This mixture is placed in an iron retort, which is set on the fire. There is given off sulphurous acid, oxygen, and sulphur vapor, the matter in the retort being probably sulphide and sesquioxide of manganese. This method, not giving a very pure product, is not well adapted for many purposes. The method generally adopted is that of robbing sulphuric acid of one equivalent of oxygen by any convenient body. A mixture of strong oil of vitriol and charcoal heated in a flask, which has a conducting tube—Fig. 571—attached, serves very well, if absolutely pure gas be not needed. The gas given off by the mixture is a compound of SO_2 and CO_2 . The following being the reaction—



But sulphurous acid as nearly pure as possible, in fact quite pure, if made to traverse a little water to take up any sulphuric acid, may be obtained by heating sulphuric acid with one-third its weight of copper, in the shape of turnings or clippings. One atom of copper takes up one atom of oxygen from one atom of sulphuric acid, and becomes oxide of copper, which itself immediately combines with another equivalent of sulphuric acid, forming sulphate of copper—



Mercury may be substituted, but with no advantage—a like reaction takes place. The sulphurous acid so obtained is permanently gaseous at the ordinary atmospheric pressure, but is capable of assuming the liquid form, like carbonic acid, sulphide of hydrogen, and sundry other gases, at an increased pressure with a very low temperature. FARADAY employs a pressure of from three to five atmospheres; WACH places in a long glass tube, sealed at both ends and bent in the middle, a mixture of anhydrous sulphuric acid and sulphur. This is heated, while the opposite end is kept immersed in a freezing mixture. Sulphurous acid is formed under strong pressure, and condensed in the cooled end of the tube. In order to obtain it pure, it must be run to the other end of the tube, and again distilled to free it from sulphuric acid. Sulphurous acid in the liquid state is only of scientific interest; it is like many other rare chemical preparations, which are only made at a cost of great labor, and when made, can only be preserved conveniently for a very short time. As a liquid its boiling temperature is 14° .

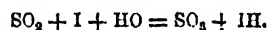
As far as all the useful properties of sulphurous acid are concerned, they may be studied from its solution in water, this liquid taking up, at mean temperature, thirty-three times its bulk of the gas.

Sulphurous acid solution is obtained by passing a stream of the gas through cold water, employing for the generation any of the methods just given. A series of WOULD'S bottles, or other convenient apparatus, may be employed for the condensation. The contents of the first bottle should always be rejected, as it will contain a considerable quantity of sulphuric acid, carried over both mechanically and in a state of vapor; the other will be a nearly pure solution of sulphurous acid.

Sulphurous acid is capable of forming a crystalline hydrate with water. It is procured by exposing sulphurous acid vapor with water, in a tube or other apparatus, to a low temperature, by placing this tube in a freezing mixture. Solid sulphurous acid may be procured by rapidly evaporating the liquid acid—it forms white flakes. It is heavier than the liquid, and freezes at *minus* 110° . It is composed of—

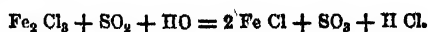
Sulphur vapor, ... 1 } forming 6 vol. of spec. grav. 2.2113.
Oxygen gas, ... 6 }

Sulphurous acid is a powerful deoxidizer, instantly decoloring acid solutions of the manganates and chromates—in the latter case reducing them to the state of green sesquioxide of chromium. For analyzing the commercial sulphites, it is only necessary to weigh out a stated quantity of the sulphite or hyposulphite to be examined, dissolve it in water, make it acid with hydrochloric acid, and then to note the number of measures of a normal solution of bichromate of potassa required to be added to convert the sulphurous into sulphuric acid, and data are obtained from which the amount of sulphurous acid contained in the sample may be easily calculated. This reducing property of sulphurous acid has been turned to advantage by BUNSEN, in the indirect analysis of various bodies—for instance, in the valuation of manganese. He places the manganese in a flask, treats it with hydrochloric acid, passes the evolved chlorine into a solution of iodide of potassium; each atom of chlorine sets free an atom of iodine. When the operation is over, he disconnects the vessel containing this iodine, and adds from a burette a normal solution of sulphurous acid until the precipitated iodine has disappeared. Each equivalent of iodine converts an equivalent of sulphurous into sulphuric acid, as follows—



Thus, tracing the reaction back, one equivalent of sulphurous acid represents one equivalent of binoxide of manganese—this principle is applied in a variety of ways. The deoxidizing power of sulphurous acid is taken advantage of by the chemist in the estimation of arsenic. When arsenic exists as arsenic acid, it is very slowly thrown down by sulphide of hydrogen; whereas arsenious acid is easily precipitated. Sulphurous acid possesses the power of abstracting part of the oxygen from arsenic acid, reducing it to arsenious; so that, if a stream of sulphurous acid be passed through the arseniate to be analyzed, after making it acid with hydrochloric acid, it is converted into arsenious acid, which facilitates its precipitation when one comes to employ sulphide of hydrogen.

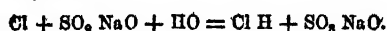
Sulphurous acid, passed through a dilute solution of yellow sesquichloride of iron, quickly reduces it to a protosalt—



Sulphurous acid reduces salts of gold, throwing down the gold in the metallic state. It is capable of taking up the second equivalent of oxygen from almost every metallic binoxide.

Sulphurous acid, in the shape of sulphite of soda, has been an article of commerce for some time, under

the half-fanciful and half-true appellation of antiechlor. It has derived its name from the use to which it is applied, being used to correct the evil effects of an overdose of chlorine. In the bleaching of paper pulp, if any excess of chlorine or hypochlorite has been used, the sulphite, on being added, neutralizes it. If, for the sake of illustration, we imagine chlorine to have been used, then—

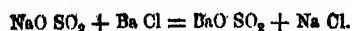


This hydrochloric acid can be taken up by any alkali, or will itself decompose a fresh portion of the sulphite, driving off sulphurous acid.

Sulphites are used by some in the manufacture of beet sugar. PROUST recommended them and a sulphurous acid solution as being antiferments, and having also other advantages. The following method of procuring it in large quantities was proposed by CALVERT, in a lecture lately delivered before the Society of Arts. He constructs a sulphur oven, such as is used in the manufacture of sulphuric acid. Within this oven the sulphur is burned, producing sulphurous acid. An earthenware tube, immersed in water, leads from this burner or oven to a tall wooden column filled with pumice-stone, or other suitable porous body. A cistern of water is placed on the top of this column, to which cistern a tap or valve is attached, by means of which a shower of water can be sprinkled on the pumice-stone, keeping it in a moist or wet state. The mixture of gases issuing from the burner, consisting of sulphurous acid, atmospheric air, and residual nitrogen, pass along the conducting tube, enter the column near the bottom, and pass up its whole length, thus meeting with the descending water; the sulphurous acid is absorbed, and a constant stream of the solution issues into a cistern placed at the bottom for its reception, while the residual gases pass out into the atmosphere.

Some brewers employ a solution of sulphurous acid to rinse out beer barrels after washing, as it possesses the property of arresting the acetic fermentation.

Sulphurous acid, when present in a free state in small amounts, is easily detected by its suffocating odor. It does not, like sulphuric acid, give any reaction with a salt of baryta, except when combined with a base. This is on account of the sulphite of baryta—unlike the sulphate—being soluble in free acid. When sulphuric acid is added to a salt of baryta, sulphate of baryta is formed, and the acid with which the baryta was previously combined is set free. But this acid can exert little or no action on the sulphate of baryta. Now, on adding sulphurous acid to a salt of baryta, the sulphite of baryta would dissolve in the acid set free, and which was previously combined with the baryta. But in the case of a salt having sulphurous acid in its composition, this does not occur. No acid is set free to exert a solvent action. For instance, if to a solution of chloride of barium is added a solution of sulphite of soda, a white precipitate of sulphite of baryta will be produced—



Supposing it to have been doubtful whether the salt employed was a sulphite or a sulphate, one can now determine the point by the addition of an acid, say

hydrochloric acid. Sulphite of baryta being soluble in this acid, the precipitate will disappear if the salt was a sulphite; if the precipitate is persistent, a sulphate is indicated. Of course, both may be present.

An old specimen of sulphite is sure to contain a quantity of sulphate, formed by oxidation, even though pure originally. To determine absolutely the presence or absence of sulphurous acid in a body, it is only necessary to dissolve it in hydrochloric acid, if solid, or if a liquid, make it acid to the same extent, and add a few scraps of zinc, such as is used in the production of hydrogen gas. If the body under examination contain sulphurous acid, the hydrogen going off will be accompanied by sulphuretted hydrogen, which may be detected by the smell, or by its blackening paper dipped in a solution of a lead salt. This test will discover very minute quantities of sulphurous acid. Such is its delicacy that sulphurous acid may be detected in much of the commercial hydrochloric acid; it arises from the action of the strong sulphuric acid on the iron decomposing vessel employed. The reaction may be explained as follows, leaving out the hydrochloric acid:—



One method of estimating sulphurous acid has been given, but the ordinary method is to convert it into sulphuric acid, and then proceed in the manner followed in the estimation of that acid. This may be effected by several oxidizing bodies. It is sometimes recommended to employ nitric acid, but there is a chance of error by doing so, inasmuch as a quantity of the sulphurous acid may escape whilst heating it. Perhaps the best method is to pass through the sulphurous acid or the sulphite to be analyzed a current of chlorine until the liquid smells of the latter gas, placing it on a sand bath until all smell has disappeared, then precipitate with a salt of baryta, collect, wash, ignite, *et cetera*, exactly as indicated under the head SULPHURIC ACID.

Sulphurous acid forms, with bases, a series of salts called sulphites, one of which has been already mentioned, the sulphite of soda. These sulphites have been shown by the Editor to bear a strong resemblance to carbonates, being also isomorphous with the latter salts. The following list proves the analogy:—

Sulphites	Carbonates
KO, SO ₂ + 2 HO	KO, CO ₂ + 2 HO
KO, SO ₂ + HO, SO ₂	KO, CO ₂ + HO, CO ₂
NaO, SO ₂ + 10 HO	NaO, CO ₂ + 10 HO
NaO, SO ₂ + HO, SO ₂	NaO, CO ₂ + HO, CO ₂
NaO, SO ₂ + HO, SO ₂ + 8 HO,	NaO, CO ₂ + HO, CO ₂ + 8 HO
BaO, SO ₂	BaO, CO ₂
SrO, SO ₂	SrO, CO ₂
MgO, SO ₂ + 3 HO	MgO, CO ₂ + 3 HO
MnO, SO ₂ + 2 HO	MnO, CO ₂ + 2 HO
PbO, SO ₂	PbO, CO ₂
AgO, SO ₂	AgO, CO ₂

Sulphite of soda is the only salt—with the exception of a mixed sulphite of lime and magnesia—which is manufactured on a large scale. Sulphite of soda is made by passing a stream of sulphurous acid gas through a solution of carbonate of soda; the carbonic acid is displaced, and sulphite of soda is formed. On the large scale, the same method as is pursued in the

manufacture of bicarbonate may be followed for the production of the sulphite. A chamber or suitable large vessel is so constructed with appliances that a stream of sulphurous acid from burning sulphur may be drawn through. This chamber or vessel is filled with crystals of carbonate of soda; the stream of sulphurous acid in its passage through the interstices of the mass is taken up, carbonic acid being evolved. The passage of the gas must be continued until a sample taken out of the chamber, on being dissolved, has an acid reaction with litmus paper. The mass of what was originally carbonate of soda has now become a mixture of sulphite and bisulphite of soda. This is now dissolved in water, and brought to the boiling point; a solution of carbonate of soda must now be added, until the last addition causes no evolution of carbonic acid; the whole is now brought to the state of neutral sulphite; and after standing to deposit any mechanical impurities may be run off into a suitable vessel to crystallize.

The sulphites of potassa and ammonia may be prepared in a similar manner to that of soda, by passing sulphurous acid through a solution of the alkalies or their carbonates.

The sulphites of the alkaline earths are prepared either by exposing the moistened, or better, the hydrated oxides, to gaseous sulphurous acid, when this gas is absorbed; or the oxides or carbonates may be suspended in water, and a stream of sulphurous acid passed through; or they may be produced by double decomposition from a soluble alkaline sulphite, and a chloride of the earthy metal. These sulphites are all more or less nearly insoluble in water and alcohol, but are rendered more soluble by an excess of sulphurous acid, in this respect resembling the carbonates. The only practical purpose to which any of these earthy sulphites have been applied, is as disinfectants. For this purpose, a mixture of the sulphites of lime and magnesia is used. Mr. M'DOUGALL seems to have a method of producing sulphites much more readily than any other maker.

The sulphites of the metals proper, such as iron, zinc, lead, bismuth, *et cetera*, are produced by analogous processes; they, like the earthy sulphites, are more soluble in a solution of sulphurous acid than in pure water.

SULPHURIC ACID—*acid sulphurique*, French; *schwefelsäure*, German—is the most stable and the best known oxide of sulphur. It appears to have been known from very early times. BRANDE, in speaking of it, says that the honor of its discovery is due to BASIL VALENTINE. He frequently mentions it and its mode of preparation; and PARACELSUS, and the authors who immediately followed, talk of it as well known and in common use, though it is probable that it bore a high price, and was but scantily supplied by a few awkward and unintelligent operators. But KOPF shows evidently that VINCENTIUS DE BEAUVAIS had an idea of the substance obtained by distilling alum. BOYLE first recognized in it a relation to sulphur. MAYOW pointed it out with great clearness, but he was far before his time in penetration. STAHL believed sulphur to consist of sulphuric acid and phlogiston, a theory in conformity with the rest of his system.

LAVOISIER showed the formation of acid by sulphur taking up oxygen, but it had been made by burning sulphur in the air, at least since the time of LEMERY and Dr. WARD. Sulphuric acid exists, as free acid, in two states, liquid and solid—the liquid being a combination of dry acid and water. The right of the dry body to be called sulphuric acid is doubted, as it exhibits no acid characters until combined or mixed with water. The character of the acid is sufficiently shown in the reactions of the monohydrated sulphuric acid— SO_3 , HO —or the purified oil of vitriol. This body is a heavy fluid, above three-fourths heavier than water. It flows when poured from one vessel to another, in a heavy, smooth, *oily* stream. This oily appearance has, doubtless, given it its name; and although this appellation, oil of vitriol, has been much ridiculed, it cannot be disputed that it is very expressive, and serves well to distinguish the strong vitriol from the dilute acid, which bubbles like water when poured. Oil of vitriol has a strong attraction for water, so much so that a bottle containing it, if left open, rapidly attracts moisture from the air, becoming itself much weaker. This property is often taken advantage of in analytical operations. When a stream of dry gas is needed, it is simply requisite to pass it through strong sulphuric acid, or through a wide tube filled with fragments of coke or pumice-stone saturated with the acid. This is a very effectual mode of drying a gas. It is not applicable to certain gases, between which and the sulphuric acid a reaction might take place. In the simple and elegant apparatus, devised by FRESSENIUS and WILK, for the estimation of carbonic acid, sulphuric acid is employed for the purpose of desiccating the carbonic acid before it emerges from the apparatus. It has been stated that sulphuric acid possesses the property of absorbing carbonic acid, and that consequently the operations in which its drying property has been taken advantage of cannot be correct. This, again, has been refuted; and, inasmuch as most chemists are in the habit of using this apparatus, it would appear to be tacitly allowed that if any error from this source does exist, it is so small as to be of no consequence.

This attraction of sulphuric acid for water also brings about some curious decompositions with organic bodies. For instance, if any of that class of bodies, such as sugar, starch, *et cetera*, which contain carbon, hydrogen, and oxygen, in such proportions that, for the sake of simplicity, they may be considered as being composed of carbon and water, be mixed with strong sulphuric acid, and heated, a black mass will be obtained; and if this mass be thoroughly washed with water, so as to remove every trace of sulphuric acid, it will be found to be pure carbon, the whole of the elements of water having been removed. So effectual is the process, that the principle has been proposed as a method of obtaining peat charcoal without the ordinary charring process. This charcoal is then washed and dried. To this same property is due the occasional brown color of commercial vitriol. If particles of organic matter fall into it, a portion of their hydrogen and oxygen is abstracted, forming a humus-like body, which, dissolving in the vitriol, colors it. This attraction for

water seems to be the principle by which it acts upon the skin, and animal and vegetal matter generally. The density of this monohydrated acid is 1·850, and it boils at a temperature of 620°. Its boiling point diminishes with its density. The strong acid is perfectly volatile, and thus capable of being distilled. It freezes at a temperature of 29°, yielding often six-sided prisms of a tabular form.

This acid has the power of supplanting or displacing almost every other acid known, so great is its affinity for bases. It produces great heat when mixed with water, the compound becoming denser than the mean of the two liquids. If equal volumes of strong sulphuric acid and water be mixed, and then allowed to cool, it will be found that the resulting liquid will not make up the original two volumes; it now occupies less space, contraction having taken place. During this contraction a portion of the latent heat of the water has been given off. PARKES made a series of experiments on this matter, the results of which are given in the following table:—

HEAT PRODUCED BY THE ADMIXTURE OF SULPHURIC ACID
WITH WATER, TEN POUNDS OF SULPHURIC ACID
BEING USED IN EACH EXPERIMENT.

Sulphuric acid in pounds.	Temperature of the mixture in degrees of Fahrenheit
1	78°
2	100
3	110
4	128
5	138
6	144
7	156
8	168
9	186
10	204
11	214
12	222
13	229
14	235
15	241
16	246
17	250
18	253
19	256
20	258
25	266
30	264
35	254
40	248

But FAYRE and SILBERMANN have lately examined the question more thoroughly, and shown that the following amount of heat is given out:—

HEAT EVOLVED BY MIXING $\text{SO}_3 \text{ H}_2\text{O}$ WITH WATER.

Atom of water.		Root units	Differences
With the first $\frac{1}{2}$	.....	94.0	0.6
second $\frac{1}{2}$	.....	88.0	
With the first $\frac{1}{4}$	.....	18.8	1.6
second $\frac{1}{4}$	.....	17.2	
With the first $\frac{1}{8}$	.....	36.7	8.4
second $\frac{1}{8}$	.....	28.3	
Atoms of water.			
1	.....	64.7	29.9
2	.....	94.6	17.3
3	.....	111.9	10.3
4	.....	122.2	8.5
5	.....	130.7	5.5
6	.....	136.2	4.4
7	.....	141.8	3.3
8	.....	145.1	3.4
9	.....	148.8	0.0
10	.....	148.4	0.0
20	.....	148.6	

When four of the monohydrate are mixed with one of water by weight the temperature rises to 300°.

GRAHAM gives the following list of the hydrates of sulphuric acid—

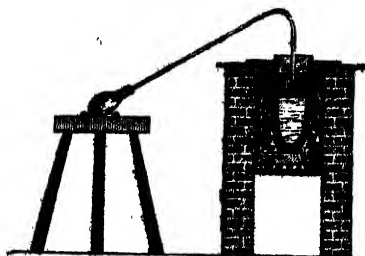
Nordhausen sulphuric acid,	=	HO, 2 SO ₃
Sulphuric acid, specific gravity, 1.850,	=	HO, SO ₃
“ “ “ 1.78,	=	HO, SO ₃ + HO
“ “ “ 1.632,	=	HO, SO ₃ + 2 HO

The third hydrate in the above list corresponds nearly to the commercial brown oil of vitriol, the density of this latter being 1.758. It is formed by heating a dilute acid to 400°. Its properties are almost identical with those of the monohydrate. It has the property of solidifying at the temperature of melting ice, or a little above this point. It is no uncommon circumstance for a sulphuric acid manufacturer to find a carboy of brown vitriol converted almost into a mass of crystals, if exposed to the cold in frosty weather. These crystals are the well-defined hydrate in question. This crystallization has been proposed as a method of obtaining pure sulphuric acid, as will be seen hereafter. Little seems to be known of the lower hydrate. It is formed by heating a dilute acid at 212°. This amount of acid and water causes the greatest condensation of volume.

Neither dry nor fuming acid can be obtained by the ordinary mode of concentration, it being impossible to drive off the last equivalent of water. Dry acid may be obtained by distilling the Nordhausen acid— HIO_3 , 2 SO_3 . But Nordhausen acid is not now a common commercial product; it is often necessary for the operator to make his own. This may be done either by distilling the protosulphate of iron or the sesquisulphate, artificially prepared; bisulphate of potassa or soda may be also used. This latter salt is the cheapest, and perhaps the most convenient. It may be procured by heating one equivalent of common salt in a crucible with two equivalents of sulphuric acid, taking care to operate under a chimney, or in some situation where the hydrochloric acid fumes will be carried away quickly. When gas has ceased to be evolved from the mixture, the residue must be heated to a low red-heat, in order to drive off as much water as possible. The fused salt must be removed from the crucible and allowed to cool. This may be done by pouring it out into an iron dish, or other convenient vessel. When cold, it must be broken up, when it is ready for the next operation. Or, instead of this, the bisulphate of soda or potassa left in the retorts, when procuring nitric acid, may be preserved for the same purpose. Porcelain retorts being very expensive, it is well to substitute, if possible, some cheaper piece of apparatus. For this purpose an ordinary brassfounder's crucible may be employed; a lid may be formed out of a piece of ordinary fire-tile—this lid has a hole cut through, into which is inserted a piece of glass tube to carry off the vapor. The arrangement is shown in Fig. 571. To commence, a piece of brick is first laid on the bars of the ordinary laboratory furnace; on this the crucible is placed; this is filled with the broken pieces of bisulphate; the lid is luted on with clay, and the tube luted into the lid. A fire is lighted around the crucible, and this is gradually increased in power, until at length

distillation commences. Weak acid at first comes over—this is emptied out of the receiving flask; eventually the retort or crucible begins to attain a good red-heat; drops of strong acid fall, and hiss as they touch the weaker acid in the flask. The flask is now

FIG. 571.



finally emptied of its contents, and replaced, the acid which now comes over being fuming acid, white vapors pour through the glass tube at a rapid pace, a portion condensing there, and a portion in the flask. The flask should be a thin one, and is all the better for being placed in a basin of cold water. After a time vapors cease to appear, and the operation is at an end. The glass tube should now be carefully taken away, as also the lid of the crucible, and the fused or softened mass, forming the contents of the latter, should be removed by means of an iron scoop. This done, the crucible should be allowed to cool slowly; when cold enough, it may be filled again, and the foregoing operation repeated. With care, a crucible will last three or four operations. The neutral sulphate may be reconverted into bisulphate, to be again employed.

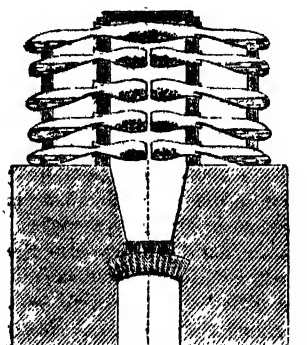
The fuming acid so obtained gives off white vapors. These white fumes are dry acid— SO_3 —vapor, combining with the moisture of the atmosphere. It makes a hissing noise when poured into water, very like the noise made when red-hot iron is plunged into a liquid. This acid is employed in gas analysis, on account of its possessing the power of absorbing certain hydrocarbons. For this purpose a piece of coke is wetted with the fuming acid and passed into the gas to be analyzed, standing in a graduated tube over mercury. To obtain the dry acid it is necessary to submit the fuming acid to distillation at a gentle heat. For this purpose a glass retort is partially filled with the fuming acid, the neck of the retort is inserted into a flask, placed in cold water, a gentle heat is applied to the retort, when the dry acid begins to come over. It condenses in solid fibres like asbestos, which are tenacious, and may be moulded by the fingers like wax. Its density at 68° is 1.970; at 77° it assumes the liquid state; and a little above that temperature it enters into ebullition. If a little of this *anhydrous* acid be placed on a slip of dry litmus paper no reddening results—coloration not taking place until moisture has been absorbed.

Manufacture of Sulphuric Acid.—The principle involved in the mode of working adopted by Dr. ROEBUCK, who may be considered the first inventor or improver, still continues in vitriol manufactories; in fact, from that time may be dated the actual rise of the sulphuric acid manufacture.

The earlier process, and, according to many authorities, the one still followed in a few places where natural advantages render it profitable, is one already alluded to, and which consists in distilling or driving off by intense heat the sulphuric acid from protosulphate of iron. This salt is dried and placed in fireproof retorts, which are built in suitable furnaces. Proper receivers are connected with them. These retorts are charged, and heat applied, until they become sufficiently hot. The sulphuric acid is driven off and condenses in the receivers, while oxide of iron is left in the retort. The following description, extracted from KNAPP's excellent work, will give a good idea of the process as followed at Radnitz:—The material operated upon is the mother liquor from the manufacture of alum. This contains a large quantity of protosulphate of iron. These mother liquors are first evaporated to a dry state, and then roasted at a gentle heat. During this latter roasting a considerable quantity of oxygen is absorbed, the protosulphate passing partially into basic persulphate of iron. These operations are conducted on the spot where the alum liquors are to be had. This roasted product, which is called *vitriolstein*, is sent to Radnitz for conversion into fuming oil of vitriol. This process consists in the dry distillation of the *vitriolstein*. The pots in which the distillation is effected are constructed of refractory stoneware, and after being baked in a kiln upon the premises, are about nine inches long, two and a half inches in diameter at the bottom, four and a quarter at the middle, and three inches at the mouth; they are about four-tenths of an inch thick in the sides. Before being used they are covered with a lute, or luting material, which is easily fritted by the action of the fire. The receivers are of much the same shape, but are longer and narrower at the mouth. The upper row in the furnace is occupied by a single range of pots twenty-eight inches in length. The gallery furnace for the reception of the pots is rectangular in section, and is composed of two parts essentially distinct. The lower part is built of massive masonry, enclosing the ash-pit and the grate, which extends the whole length under the range of pots; the upper part consists of two vertical walls of perforated brickwork, which form the sides of the furnace and support the pots. This latter portion demands frequent repair. Fig. 572 represents a front vertical section. It incloses four tiers of the smaller sized pots, arranged with their bottoms in contact, and an upper tier of long pots, which extend from one side of the furnace to the other, and are open at both ends. The whole, therefore, contains two hundred and eighty-eight pots—thirty-two large, and two hundred and fifty-six small. The long sides of the furnace are divided into squares by vertical and horizontal bricks of the same dimensions, and four pots are placed in each square, separated from each other by small bricks, the interstices being luted with refractory clay. The arch of the furnace is constructed of flat bricks, simply placed alongside each other, and cut sloping at their extremities, to allow the flame to pass. A small chimney is sometimes built to the furnace, but it is more frequently without. The pots are charged with the *vitriolstein*, previously broken up with a hammer, by means of a

semicylindrical spoon, each pot receiving two spoonfuls. The coal for the first charge is then ignited below the grate, and is thrown upon the grate at the expiration

Fig. 572.



of about an hour or an hour and a half; the fire being carefully regulated by opening or shutting the doors. At the end of four hours the lower tier of pots is brought to a dark-red heat. The receivers are successively introduced into the pots and luted, those of the second layer resting immediately upon the first, and a wooden support being introduced between the second, third, and so on. The receivers are slightly inclined, and a small quantity of water is placed in each. This is sufficient to receive the acid from four successive distillations, after which it is in the state of concentration required in commerce. The fire is gradually increased, and after from thirty to thirty-six hours no more acid is evolved from the upper tier of pots, and the distillation is finished. The whole is then allowed to cool for twelve hours, and the receivers being removed the colcothar is taken from the pots. This contains about six and a half per cent. sulphate of lime, and amounts to about thirty or thirty-five per cent. of the vitriolstein employed.

The pots are now examined by the sound which they emit when struck. The broken ones are removed, and being replaced by fresh pots, the distillation is recommenced.

Each operation lasts about forty-eight hours, and three are completed in a week. From forty-seven to fifty per cent. of the vitriolstein is obtained in fuming sulphuric acid; five parts of coal are consumed for one part of vitriolstein distilled. About thirty pots and three receivers are replaced after each distillation, which is equivalent to 10.42 and 1.04 per cent. respectively.

Although such a mode of manufacture may be capable of being followed in some localities, yet it is far from possessing the general adaptability of the ordinary process. From the above description there appears to be little loss, except from accidental leakage or the breaking of a pot; but as the process is described by many, or in fact the greater proportion of writers, simply dry protosulphate of iron is employed— FeO SO_3 —not as in the method just described, sesquisulphate— $\text{Fe}_2\text{O}_3 \cdot 2\text{SO}_3$ —or rather a basic persulphate. The employment of one or the other must make a considerable

difference in the amount of product obtained, for if any protosulphate of iron be employed, only one half of the sulphuric acid contained in it will be obtained as sulphuric acid, the rest passing off as sulphurous acid. The following is the reaction:—



Two equivalents of protosulphate of iron are decomposed into one equivalent of sesquioxide, one of sulphuric acid, and one of sulphurous acid; one of the equivalents of sulphuric acid has parted with one of its equivalents of oxygen, in order that the two equivalents of protoxide of iron might become sesquioxide. This equivalent of sulphurous acid is said to escape through the joints of the apparatus; if so, and there does not appear to be any doubt of this being the fact, inasmuch as no other provision appears to have been made for its exit, one may naturally conclude that sulphuric acid vapor must escape at the same time.

Such was the method pursued for procuring sulphuric acid for some centuries. The next process—a modification of which remains in use to this day—consisted in converting sulphur by stages of oxidation into sulphuric acid. This differs materially from the process before described, in which acid already formed was simply separated from a combination; in the present case the operation commences with the prime element. The first step in this direction appears to have been the formation of sulphuric acid in small quantities by the combustion of sulphur in glass globes, moistened on the interior surface with water. It is true that under these circumstances a small quantity of sulphuric acid would be formed, but the amount would be very minute indeed; in fact, the combustion of sulphur in pure oxygen gives rise to little more than a trace. But a grand step was made in the right direction by the introduction of nitre in the manufacture. The use of sulphur and nitre together was said to have begun with LEFEVRE and LEMERY. Dr. WARD had the monopoly of it long in this country, and best knew how to manage the process. Instead of sulphur *per se*, a mixture of sulphur and nitre was made, and set fire to in or under a bell glass; by this proceeding a much greater quantity of sulphuric acid was obtained. It can easily be imagined, that even the most successful experiment could furnish only a small quantity of acid, on account of the very limited size of the apparatus. This must strike an observer when he contrasts in his own mind the largest jar or globe that could be blown, even now, with one of the vitriol chambers of the present time. But this difficulty of limited dimensions was surmounted by a Dr. ROXBURCK of Birmingham, who was the first to introduce leaden chambers, which he did as a substitute for the comparatively small globes; and as he was able to make them of any required size, a great relief must have been given to the manufacturer. The manner of working was still precisely similar to that with the globe. The chamber had an entrance-door, which could be luted tight; this was opened, and a charge, consisting of a mixture as before of sulphur and nitre, was put on a proper stand placed to receive it in the chamber. According to some authors this was a sort of carriage, which could be pulled towards the door to receive the

charge, and then after ignition pushed towards the centre of the chamber; but it is difficult to conceive that this is true, as it would not be easy to find material of which to construct the wheels and other parts of such a machine, when it is considered that the floor of the chamber was covered with acid to the depth of several inches. It is certain that the proper charge was placed on a stand in the interior of the chamber; this was ignited, and the door was then properly fastened and luted. After a certain time had elapsed the door was again opened, and the residual gas or gases allowed to escape. This was repeated again and again, until the water with which the floor of the chamber was covered had absorbed sufficient of the acid, when it was run off and concentrated. Authors speak of a collapse of the sides of the chamber occurring, owing to the partial vacuum produced by the absorption of the oxygen of the contained air. But it can be scarcely believed that this accident could have occurred often, since it is hardly conceivable that practitioners of the chemical art at that time could have been ignorant of the fact that a very simple arrangement of a water-valve opening inwards would have remedied this.

This process, then, was the one followed by Dr. ROEBUCK, and such in principle it remains down to the present day; and had it possessed the advantage of a later invention, *vide* *supra*, the introduction of steam, it would no doubt have given an excellent result. Supposing there had been in the chamber twenty-four parts by weight of oxygen for every sixteen parts of sulphur introduced, watery vapor being also present in sufficient quantity, every particle of sulphur must have been converted into sulphuric acid, if sufficient time were allowed to elapse before the opening of the chamber door.

Having followed the manufacture to this point, one must now pass on to another step, from the intermittent to the continuous process, as practised at present. It is easy to see that had Dr. ROEBUCK burned his sulphur in a properly constructed apparatus, and introduced the resulting sulphurous acid into his chamber at one end, drawing off the residual gases at the other, he would have improved his method, and escaped many inconveniences.

If one views the gigantic scale in which this manufacture is carried on at the present day, by a TENNANT or a MUSPRATT, he must smile on looking back at the almost puny manner in which they operated in former times; but, then, add to their process the continuous system—the introduction of steam into the chambers by KESTNER, concentration in the platinum vessels, and GAY-LUSSAC's column for the recovery of the nitrous gas—and manufacturers have almost all that could be desired at present.

Much ingenuity has been expended in the construction of every piece of apparatus connected with the manufacture of vitriol. The ovens or burners, the chambers, and every part, have been tortured into a variety of forms, some of which would appear to have been devised in an idle moment, and constructed only to gratify a whim, or if any object has really been in view, it must have been imaginary. But in every manufacture where the process is understood, the difference,

except in little details, between the apparatus of to-day and that of twenty years ago, is very small. Improvement after improvement, which have turned out to be rather impediments, have been introduced, had their short reign, and disappeared, only to be succeeded by something else equally visionary. In fact, it would seem that the manufacture of sulphuric acid, though as extensively carried on as any business, yet seems to be the least understood; and the ignorance of some manufacturers appears to be only equalled by that of writers who, in their descriptions of the production of this acid, give figures of apparatus, and vaunt as improvements things which have been exploded for years. It is possible to find, in the works of eminent men, drawings of sets of apparatus for the production of sulphuric acid, which never could possibly have worked one day—some, in fact, could never have worked at all.

Production of the Sulphurous Acid.—This first step is effected by burning the sulphur in a close room or oven,

Fig. 573.

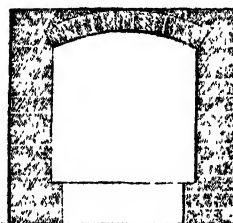
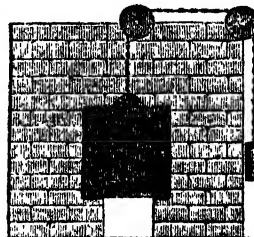
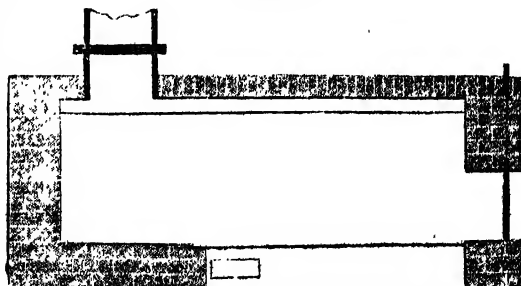


Fig. 574.



commonly called a burner. This burner is a simple erection of brickwork, with an arched roof, as shown in Figs. 573, 574, and 575. The size of the burner is regulated by that of the burner plate or iron flooring, and this latter by the quantity of sulphur proposed to be burned during seven days. The burner plate in the drawing is a rectangular iron, measuring eight feet by four feet. This burner plate is surrounded with a vertical edge or border, standing about an inch high; this border is at right angles to the plate on three sides, but on the fourth side, the one nearest to the door, it inclines outwards at an angle of about forty-five degrees—this is for the more conveniently raking out of the residual dirt and ashes left after the combustion

Fig. 575.



of the sulphur. The door of this burner is simply an iron plate, sliding in grooves in an iron framework, and is counterbalanced by a weight hanging at the end of a chain, which passes over pulleys.

As will be seen in the figure, the iron plate does not form the whole of the floor; still the sulphur is burned on it alone. The object of making the burner rather larger than the plate is to avoid, as much as possible, all risk of sublimation. To this end, also, there is a constant current of air passing beneath the burner plates and up a small chimney beside the burner. The opening through which the hot air escapes into this chimney is outlined in Fig. 575, below the burner plate. Four burners, such as this, with the burner plates of the size first mentioned, will easily convert into sulphurous acid one ton of sulphur per twenty-four hours. The quantity for each burner is divided into six portions, one of which is added every four hours.

Burners or ovens have been constructed of iron, sometimes with double sides, so as to include a sheet of air between the two plates. By this means the burners could be kept at almost any desired temperature; an arrangement could be made for causing a circulation of air if the burner should get too hot, or, on the contrary, should they get too cold, this air could be kept stagnant, and being a very bad conductor of heat, the burner would be allowed to rise to the desired temperature. It may be remarked here, that a burner should be kept so hot that each charge of sulphur, as thrown in, will ignite without any fire or heat being applied.

Iron ovens or burners have, however, almost disappeared, as they last a very short time. They gradually corrode, break into holes, and shortly become useless.

Some years ago a patent was taken out for a burner, the peculiar feature of which was its economizing, and converting to a useful purpose, the heat given off by the burning sulphur. The apparatus was very simple. It consisted of an ordinary two-flued steam boiler, for the usual fire-place of which was substituted a burner plate on which to burn sulphur. It was anticipated that by this means sufficient steam would be generated to supply the chambers. Whether it answered the desired end or not is not very clear; but from the fact that none appear to be in operation, it may be inferred that, if in use at all, it is not generally successful. In fact it is very probable that the action of the acid gases upon it would speedily destroy it, as it does the iron burners.

Combustion of Iron Pyrites.—Sulphur, *per se*, is not the only source of sulphurous acid for sulphuric acid. About the year 1835 the then King of Sicily thought fit to impose such a heavy duty on all sulphur exported from his kingdom, that the price of this article rose to an unprecedented height. It is said that at this crisis Dr. THOMAS THOMSON proposed the employment of the iron pyrites, with which different parts of this kingdom abound, as a source of sulphur. PARNELL states that Mr. HILL of Deptford was the first to employ this mineral, for the use of which he took out a patent in 1818. Since that time pyrites has come into very general use amongst one class of sulphuric acid manufacturers. The great objection to the use of pyrites lies in its containing a considerable amount of arsenic. This renders the vitriol objectionable for certain purposes, but this impurity does not prevent

its being used by the alkali manufacturers. A manufacturer of vitriol for sale would, were he to use pyrites, very likely have a quantity of his acid returned to him, and he would presently have to stop his manufactory. Not so the soda manufacturer; he is his own vitriol consumer—he uses all the acid he makes for the decomposition of common salt in the first step of soda-making. In his case the arsenic does not interfere in the least, it passes off as chloride of arsenic—As Cl₃—with the hydrochloric acid gas, and condenses into a liquid state with this latter body. Again, most manufacturers of soda are also manufacturers of chloride of lime. In this case they use up their own hydrochloric acid, employing it for the production of chlorine, which is absorbed by hydrate of lime, forming the bleaching powder of commerce. If a little of the arsenic should pass over with the chlorine, it would be absorbed by the lime, forming an insoluble compound, arseniate of lime, which would fall out, with other useless matters, when the bleacher came to make his solution. The greater portion of the arsenic would remain with the chloride of manganese, and as at present this is a useless product; it is run into the nearest gutter or sewer.

The burning of pyrites is not quite so simple a matter as the burning of sulphur, as a red heat is required. Two varieties of pyrites are ordinarily met with. One kind, of which large quantities are to be found in Wicklow, Ireland, and is imported into this country, to a considerable extent, for the use of sulphuric acid manufacturers, has the crystalline form of a cube, and is of a bronze-yellow color, very hard, so much so as to strike fire with steel. The following is the composition of a specimen, on the authority of R. D. THOMSON—

	Centimally.
Sulphur,	47.41
Iron,	41.78
Copper,	1.93
Arsenic,	2.11
Silica,	3.93
Zinc,	2.00
Insoluble matter,	1.43

This specimen is of a much richer kind than that usually obtained from this source. The proportion of sulphur very rarely exceeds thirty per cent. This ore contains protosulphide of iron in considerable quantity. The other variety of pyrites occurs in coal beds, and, in fact, is commonly known as coal brasses, fragments and seams of this mineral, may often be seen in coal, and, from their metallic and brassy appearance, have often misled the ignorant into thinking them of much greater value than they really are. According to the just quoted authority, they have the following composition:—

	Per cent.
Sulphur,	53.35
Iron,	45.07
Manganese,	0.70
Silica,	0.80
Loss,	1.18
	100.00

A variety of pyrites, known in the trade as Spanish pyrites, has of late been much employed. This is much richer in copper than the Wicklow species. On the introduction of this mineral, it was usual for the sulphuric acid manufacturer to engage to return the

spent or burnt material, for the purpose of having the copper extracted.

The general formula of either variety, when free from impurity, is Fe S_2 , that is, one equivalent of iron combined with two equivalents of sulphur, the chemical name of this compound being bisulphide of iron.

This mineral, when heated red hot, with access of oxygen, speedily loses the second equivalent of sulphur, being reduced to a simple or protosulphide— Fe S —the evolved sulphur being converted into sulphurous acid. If these favorable conditions are continued for a sufficient length of time, the second equivalent also becomes converted into sulphurous acid, sesquioxide of iron remaining. The whole decomposition may be represented as follows—



As may be imagined, the ordinary burner, as used for sulphur alone, lately described, is not adapted to burn pyrites; a burner of peculiar construction is required. The burner for this purpose is, in general structure, not unlike a lime-kiln. In the case of burning sulphur itself, the object is to spread a layer on a flat plate, so that, when fused and burning, it exposes a large surface for the current of air to sweep over; this is necessary on account of the fusion of the sulphur. But pyrites does not fuse except at a very high heat. The pieces retain their shape; and as it is imperative that they shall attain a red heat, it is necessary to burn them in such a manner that a mass of them can be kept together.

The structure of a pyrites kiln is shown in Figs. 576 and 577. In Fig. 577 the pyrites is shown as inclosed on two sides by two sloping walls, the back and front walls being vertical. The mass of pyrites rests on

for the purpose of arresting, as much as possible, the passage of arsenical vapors. The arsenic falling in a solid state is removed from time to time. Fig. 576 is a view of one of these kilns looking in another direction, endwise; *a* is the charging door through which fresh supplies of the mineral are thrown in at stated intervals. This door is kept closed, except for this purpose. At *b* another opening exists, but this is usually closed temporarily with bricks—it is only occasionally used. Sometimes the combustion goes on at a rate so rapid that the pyrites becomes fritted, or enters into a semifused state. Sometimes the whole mass gets fused together by its points of contact. In such a case the brick closure is removed for the purpose of introducing a crowbar, or other such instrument, in order to break up the mass or create a passage through. The coal pyrites is much more liable to this mishap than the Wicklow variety, partly on account of the bisulphide contained in it being actually rather more fusible, and partly because the coal brasses contain a certain amount of bituminous matter, which, in burning, raises the heat of the whole mass to a higher point than the Wicklow kind ever attains. The orifices, *c* and *d*, are those through which the sulphurous acid passes either into the next kiln or into the general passage.

It is not usual to see an isolated single pyrites kiln; there are often a number at work. Two are placed at the back of those shown in the drawing, forming a solid square. This answers a double purpose—it economizes brick and iron, and conserves the heat.

When commencing to burn, it is necessary to make a fire of coal or coke within the burners, having previously closed up the passage or entrance into the chamber, and opened one into the outer air. This fire heats up the sides, *et cetera*, of the kiln, high enough to ignite the pyrites when thrown in. The first few charges of pyrites are often mixed with coke to assist the combustion, until the whole mass has attained a red heat throughout. The carbonic acid resulting from this can do no harm.

The residual mass left after burning, and which consists principally of sesquioxide of iron mixed with more or less protosulphide, was at one time rather an annoyance than of any value to the manufacturer; but at the present time many of them have erected furnaces for the express purpose of extracting the small percentage of copper which it contains.

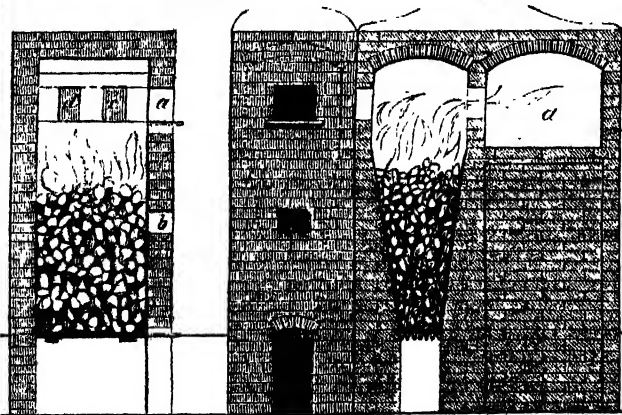
The quantity of sulphuric acid obtained from a given weight of pyrites of course cannot be as much as from sulphur, inasmuch as pyrites,

iron bars in the same manner as an ordinary coal fire, the air rushes up from what, in the case of an ordinary furnace, would be the ash-pit, and wends its way through the crevices and interstices of the mass to feed the combustion. The sulphurous acid from the first kiln passes over the next in the direction of the arrows, the gases from both flowing into the general passage, *a*, leading to the chamber. This general passage is often made of a considerable length, usually of from thirty to forty feet. This extreme length is

to take a general average, will not contain more than forty per cent. of sulphur; as a rule, a corresponding amount of sulphuric acid is not obtained from it. Much care and attention is required to burn pyrites well. It is no uncommon thing to find, on examining the waste pyrites heap of a manufacturer, that a great quantity has been removed little more than half burned. On breaking a lump a core or kernel of raw mineral may often be found; whereas well burned pyrites should not contain more than two and a half to

Fig. 576.

Fig. 577.

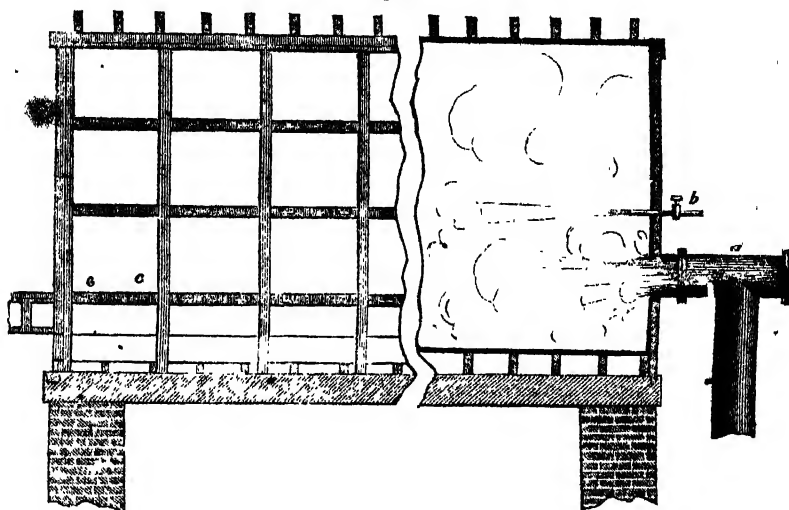


three per cent. of sulphur. Any amount more than this is in fact so much material thrown away.

General Construction of the Vitriol Chamber.—Having described the preliminary steps, the Editor now passes on to the chambers themselves. These have undergone many modifications. The chamber, as generally constructed, is simply a large room with leaden walls. A portion of one is shown in Fig. 578. These walls are generally formed of what is technically termed five-pound lead—that is, sheet lead weighing five pounds

per square foot—which walls are held up by a suitable framework of wood, to which they are fastened by what are called straps. These straps are pieces of lead, varying in number and size according to the dimension of the chamber. They are soldered or fastened by one edge to the sheet or sheets of lead forming the chamber side. The outer edge is pulled out over the wooden cross bar, and there nailed as shown at *a*, Fig. 578. The joints of the sheets of lead forming the chamber were formerly soldered with ordinary solder;

Fig. 578.



but this entailed a long series of annoyances in consequence of the action of the acid on the solder. The chamber leaked perpetually, and great inconvenience resulted. Eventually the expedient of welting was hit upon. This consisted in rolling the two edges of the sheets together and beating this flat; but this at last gave way to the method at present followed, *videlicet*, fusing the two edges of the sheet together by means of the oxyhydrogen blowpipe. For this purpose an apparatus is constructed which furnishes a constant and pretty strong current of hydrogen gas. This when mixed with a proper amount of atmospherical air projected from a pair of bellows furnishes the blowpipe. To use it the workman proceeds as follows:—He lays the edges of the two sheets together as closely as possible; every particle of dirt and oxidized or tarnished surface is scraped off; the flame is now applied in a peculiar manner, acquired by practice, and the two edges are joined together; thus making a solid joint of pure lead, as incapable of being acted upon as any part of the sheet. The plumbers who undertake the erection of these chambers are able to join two sheets of lead together even when the joint is in a vertical direction; but as it is rather a difficult and tedious business, they contrive to do as much as possible of it in a horizontal direction.

No rule can be given for the shape or dimensions of a chamber. Manufacturers are guided partly by convenience, partly by the size of the lead sheets procurable, and partly by a desire to have as much space as

possible included in the chambers with the least expenditure of lead. It is with this view that many chambers of vast size, and in shape as near as possible a cube, are being built. Of course, the nearer a chamber approaches a cube in shape, the more absolute chamber room is gained for the lead expended. It is now becoming usual to build chambers of enormous size, with the view of economizing lead. In order that a comparison may be drawn between the old mode of manufacturing sulphuric acid, and the way of proceeding at the present time, some dimensions of chambers at present in work may be given; but it is generally admitted that the best produce is obtained from a series of small chambers, in which one would burn equal to a ton of sulphur *per diem*.

Mr. SCHOLEFIELD, chemical manufacturer, of Bradford, near Manchester, possesses a chamber of the following dimensions—seventy feet long, thirty-five feet wide, and thirty-five feet high; thus possessing the enormous space of eighty-five thousand, seven hundred and fifty cubic feet. The same gentleman has also another large chamber, rather less than this one. It is forty feet long, thirty-five feet wide, and twenty-five feet high. Mr. SPENCE, also, of Newton Heath, alum manufacturer, has a fine chamber of the following dimensions: seventy-five feet long, forty feet wide, and forty feet high; containing, of course, one hundred and twenty thousand cubic feet of internal space.

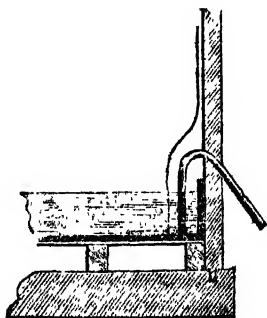
These are not the only ones—chambers of similar

magnificent dimensions are being built in many parts of Lancashire; and at Flint, North Wales, at the gigantic factory of MUSPRATT BROTHERS and HUNTLEY, chambers are of the following dimensions: one hundred and forty feet in length, twenty-four and a half feet wide, and nineteen and a half feet high; the internal space being therefore, sixty-six thousand, eight hundred and eighty-five feet. The above instances are singled out as illustrations of the chambers of the present day.

It will be easily understood that the size of the chamber, or rather the chamber space, must bear some relation to the sulphur burned. Some manufacturers are more successful than others in this respect, being able to produce more vitriol in rather less space than others, probably owing to some variation in working. In a Lancashire work, possessing chamber space to the extent of one hundred and twenty-four thousand, two hundred and sixty-eight cubic feet, they are able to convert eighteen tons of sulphur into sulphuric acid per seven days, the chambers being arranged in the form shown in Fig. 580, to be referred to hereafter. It may be well to notice, that when working with plenty of chamber space less nitre is needed. The reason will be seen when the theory of the action in the chamber has been studied.

As a general illustration of the construction or principle of a sulphuric acid chamber, it may be said to resemble a bell-jar, as used in the ordinary manner for gas experiments. In this case the bottom resembles a large square basin, into which the chamber appears to have been inverted, like the before-mentioned bell-jar in a saucer of water. This is shown in Fig. 578. The height of this basin edge, or turn-up, as it is technically termed, is about twelve inches. Into this, as in the figure, the side dips, and a light water lute joint is produced. By pushing the chamber side a little inwards—as in Fig. 579—from the turn-up,

Fig. 579

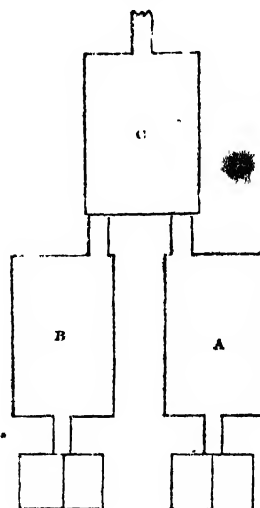


a space is formed in which the shorter leg of a siphon can be put, for the purpose of drawing off the contents of the chamber as wanted.

It is seldom that one single chamber is worked by itself, at any work, unless it be a very small one. The usual plan is to work a greater or less number from one into another. An arrangement is figured in PAYEN'S work, in which some five chambers are represented as forming a battery, the gases proceeding from

one to another through the whole series. But it is not usual to see such a number connected together. In this country, at least, the number is often limited to two or three chambers working into each other. This answers very well. A favorite arrangement is shown in Fig. 580, which represents three chambers connected together. The chamber, A, has one or two

Fig. 580.

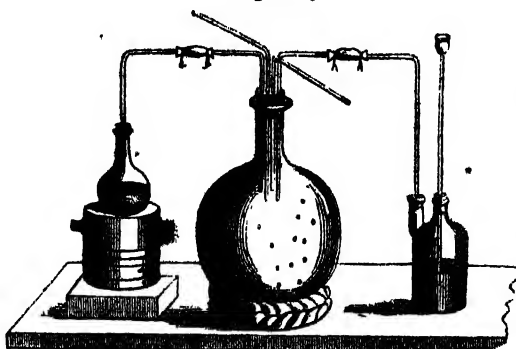


burners attached to it; the same with chamber B. The gases generated in these ovens rise through a cast-iron stalk or chimney into A and B. The portions which escape condensation into these chambers, are conveyed through the passages shown in the drawing into C—the third chamber. If any residue remains it passes with the waste gases into the chimney, through the tube at the end.

Theory of the Production of Sulphuric Acid.—The production of sulphuric acid in the chambers is the result of a series of rather complicated reactions. It was sufficient for the old manufacturers to know, that certain bodies placed in certain relative positions produced sulphuric acid; but for the present day this is not sufficient. The reactions of the different gases and vapors on each other, have been repeatedly studied, and much difference of opinion exists on this head. The reactions are very curious and interesting, the chief being the remarkable and useful property of the nitrous constituent of the chamber gas—of acting as a carrier of oxygen to the sulphurous acid. Were nitric acid capable of yielding up at once the whole of its oxygen to the sulphurous acid, it would require eighty-five parts of nitrate of soda to furnish nitric acid sufficient to oxidize the sulphurous acid produced from eighty parts of sulphur, so as to convert it into sulphuric acid. But in practice one hundred parts of sulphur are converted into sulphuric acid with the aid of from five to ten parts, according to the way of working, of nitrate of soda. This is rather startling; but chemists have traced out the fact, that though atmospheric oxygen is itself incapable of at once combining with sulphurous acid, eventually it is from

this source that the extra oxygen is supplied. The reaction may be studied on the small scale by the aid of the apparatus, Fig. 581, which may for the purpose be considered a sulphuric acid chamber in miniature. This apparatus consists of a large flask or balloon. In

Fig. 581.



this the action is to go on, the flask is to furnish sulphurous acid, while the Woulfe's bottle is for the production of nitric oxide by the action of nitric acid on slips of copper. Tubes from both these pieces of apparatus conduct the respective gases into the large globe, which globe has also two other tubes inserted through its perforated cork—one is for the purpose of introducing atmospheric air, while the other is the exit pipe for the residual gases, *et cetera*. The apparatus is set to work in the following manner:—A small quantity of water is introduced into the large globe. This is turned about until the sides have been wetted. Copper turnings are placed in the two-necked bottle and in the flask, and the whole apparatus is fitted together as shown in the drawing. An ounce or two of strong sulphuric acid is now poured on to the turnings in the flask, and heat applied; as explained under sulphurous acid, this gas begins to be evolved. When a steady stream begins to be given off, a quantity of commercial nitric acid, diluted with about half its bulk of water, is poured into the Woulfe's bottles through the tube funnel with which it is furnished. A stream of nitric oxide— NO_2 —begins to be evolved immediately. This, soon as it comes in contact with the air in the globe, takes up another equivalent of oxygen, becoming peroxide of nitrogen— NO_4 . A reaction now ensues between this and the sulphurous acid from the flask. The NO_4 combines with the SO_2 —sulphurous acid—forming, it is supposed, a compound having the following formula— $\text{NO}_2 \cdot 2(\text{SO}_2 \cdot 2\text{HO})$ —water being present; or to follow the decomposition—



This, added to another equivalent of sulphuric acid already formed, the product of a previous action, makes up the formula before given. This latter body makes its appearance as an icy crust on the sides of the globe. Join one of the two open tubes on to a gas holder, or aspirator, and cause a small current of air to be drawn or forced through, to replace the oxygen absorbed by the nitric oxide— NO_2 ; remove this when done, and join on a small retort, or flask containing boiling water;

and now drive a small jet of steam into the balloon. Immediately the steam enters, the frosted coating will melt off the sides and decompose, streams of acid will run down the sides of the globe, and the whole interior will become filled with red fumes. If thought proper, the experiment can be repeated; it is only necessary to throw in a fresh quantity of sulphurous acid. This will again decompose the peroxide of nitrogen, forming the same compound as before—thus the experiment can be gone over several times. In this experiment, it is generally supposed that one has in miniature the action of a chamber; but this is scarcely the exact truth, inasmuch as the circumstances, though very nearly, are not quite the same as on the large scale; and daily experience teaches, that a small difference of circumstances will sometimes produce a great difference in a reaction. In the vitriol chamber itself, all the necessary re-agents are present at the same time, so that it is not unreasonable to suppose that some variation from the above described experiment may take place.

Almost every chemist who has studied the subject, has taken a different view of the question; though all appear to concur in supposing that the formation of the crystalline compound precedes the formation of any sulphuric acid. On this account most ingenious theories have been broached, explanatory of the decomposition which ensues. All concur in the opinion that it is nitric oxide which is evolved when the crystals come in contact with the water. With a view to elucidate the subject, these crystals have been repeatedly analyzed, but the analyses differ much. Dr. THOMSON gave their composition as— $3 \text{SO}_2 + 2 \text{SO}_3 + \text{NO}_2 + \text{H}_2\text{O}$ —a scarcely probable combination. Dr. HENRY again, from his examination, considered them to be composed of— $5(\text{SO}_2 \cdot \text{NO}_2) + 5 \text{H}_2\text{O}$ —a more likely supposition. The analysis of these crystals must always be a difficult matter. It is impossible to procure them absolutely pure; and even were they obtained pure, they are so very prone to decomposition, that it is almost as difficult to keep them so for the purpose of analysis.

The theory of the chamber reaction just given, and which first originated with CLEMENT and DESORMES, is the one held by many chemists, including KNAPP, who gives it in his *Technology*; but there are others who hold that the decomposition and recombination of nitric acid is an essential part of the chamber reactions. Amongst these latter may be named PELIGOT, quoted by R. D. THOMSON. PELIGOT considers that there are four phases in the process. The first is the mutual reaction of sulphurous acid and nitric acid, the products being sulphuric acid and peroxide of nitrogen— $\text{SO}_2 + \text{NO}_2 = \text{SO}_3 + \text{NO}_4$. Two equivalents of this NO_4 combine, forming nitric acid and nitrous acid— $2 \text{NO}_4 = \text{NO}_3 + \text{NO}_2$. This nitrous acid again, under the influence of water, is decomposed into nitric acid and binoxide of nitrogen— $3 \text{NO}_2 = \text{NO}_4 + 2 \text{NO}_2$ —which two equivalents of binoxide of nitrogen unite with two equivalents of free oxygen, becoming once more peroxide of nitrogen, which eventually becomes nitric acid by a repetition of the last three decompositions just traced out. The nitric acid formed at these several

stages acts, of course, exactly as in the first instance. Nitric acid is very easily decomposed by sulphurous acid. This may be illustrated by wetting the interior of a bell-jar with nitric acid, then placing it over a capsule of burning sulphur, and setting on a tile or plate; in a few seconds the jar becomes filled with red fumes, the sulphurous acid having abstracted a portion of oxygen from the nitric acid, reducing it to peroxide of nitrogen.

It has thus been attempted to indicate a possible means of one portion of nitric acid or nitrous gas acting *ad infinitum*, converting an almost endless quantity of sulphurous acid into sulphuric acid, without being itself diminished. Notwithstanding the amount of study and labor bestowed on this question, it is doubtful whether chemists have arrived at more than an approximation to the actual reaction in the chamber. When the very changeable nature of all the bodies which there react upon each other is considered, one can scarcely hope to attain the actual truth. The explanations just given of the formation of sulphuric acid, though doubtless such as take place, are probably only two of many; it is likely that a variation in the action of these bodies on each other is perpetually taking place, as there is a deficiency or an excess of nitrous gas, more or less steam, a greater or less quantity of atmospheric air present, a higher or lower temperature, and many other causes may vary these changes; yet one has a tolerably clear view of the general mode of action. It is a general and wide-spread opinion, that the formation of the crystalline body invariably accompanies the formation of sulphuric acid; whereas in practice its appearance is only accidental. That these crystals should be constantly formed under the ordinary working condition of the chamber is almost impossible, when their great instability when in contact with water is considered, and, as in the atmosphere of a chamber properly worked, a great amount of aqueous vapor always exists, their formation is not very probable; for one can scarcely imagine that a body can be produced under such circumstances, that, were the same body ready formed to be so placed, it would be decomposed. Still, these explanations serve to show how it is possible for a small quantity of nitric acid or nitrous gas to convert a large quantity of sulphurous into sulphuric acid, acting as a carrier between the oxygen of the chamber and the sulphurous acid, constantly taking from one and immediately delivering up its plunder to the other. In order to understand the extent of this action, a previous statement must be remembered of the amount of sulphuric acid which a given weight of nitre could produce, were its oxidizing powers limited to the oxygen contained within itself. It is only from this view that the beauty of the chamber reaction is seen; and perhaps no other metamorphosis is, when looked at in a scientific point of view, so beautiful. It is the hinge and turning-point of the whole manufacture; for were it not possible to produce such a large amount of vitriol with the expenditure of such a small quantity of the most expensive ingredient, the commercial value of vitriol would of course be proportionally higher; and as this acid is the starting-point of almost every other chemical salt or body manufactured, these various

salts, *et cetera*, could not be produced nearly so cheaply as at present. As a result of this, the value of all printed and dyed goods would be considerably enhanced, and would be placed out of the reach of many, or at least not easily attained. On the cheapness of this class of articles also, industry in many places depends; so that one may trace much of the trade and prosperity of the country to this beautiful, if not very simple reaction; for though it is possible to produce sulphuric acid without the intervention of nitric acid, none of the methods which have been proposed for the purpose, have gone much further than a laboratory experiment. In a later portion of this article some of these methods will be given.

Having now followed the theory of vitriol-making on an experimental scale, the subject next to be considered is the actual manufacture in the chambers. The construction, *et cetera*, of these, and their various appurtenances, has been already noticed. The chamber arrangement described previously—Fig. 578—has two burners to each chamber; that is, to each of the chambers, A and B. The mode of working these burners is such that a constant stream of gas is sent into the chambers. In order to effect this the burners are charged alternately. Thus, if the two burners attached to a chamber be designated A and B, they are charged at the following hours:—

Burner A.		Burner B.	
Charged at	6 A.M.	Charged at	8 A.M.
"	10 A.M.	"	12 noon.
"	2 P.M.	"	4 P.M.

The same proceedings are gone through with respect to the other two burners. By this mode of charging alternately, it is supposed that as the combustion in one burner loses in intensity the other increases, and *vice versa*; so that a stream of equal volume, or nearly so, is kept up during the whole time.

The burners are charged at the above intervals with a weighed or measured quantity of sulphur. The workman lifts the sliding door, and throws in the charge. Previously to this he inspects the state of the chambers, to enable him to judge what quantity of nitrate of soda he shall decompose simultaneously with the combustion of the sulphur. He puts as much nitre as he thinks necessary into one, two, or more hemispherical iron vessels, or cups, technically termed nitre pots. Immediately he has thrown in the sulphur, he closes the door to prevent the escape of gas; he then proceeds to add to each pot already containing nitre, as much sulphuric acid—from a vessel placed for convenience near the burner—as he considers necessary. This is not a nice or exact operation, the chief point being to add rather an excess of this acid, so as to insure the total decomposition of the salt, leaving a bisulphate of soda, or a mixture of neutral sulphate and bisulphate. When these pots are charged, the door is again opened, and the workman in charge lifts the pots by means of an iron hook, constructed for the purpose, and places them in the burner, in the midst of the now partially ignited sulphur. After a while the sulphur is in a gradually advancing state of thorough combustion, and considerable heat is evolved, which, acting on the nitre pots, causes the complete decomposition of

their contents; the nitric acid is given off, and passes simultaneously with the sulphurous acid into the chamber. A method common on the Continent, but rarely now, if ever, practised here, is the employment of strong, liquid nitric acid, contained in basins, and placed inside the chamber at different parts on glass and porcelain triangles. Prefixed to the working chamber is another small one, through which the whole of the sulphurous acid has to pass, while in it are placed a number of earthenware dishes, containing nitric acid. In some instances they are not exactly dishes, but piccos of earthenware apparatus, constructed for the purpose, over which nitric acid is trickled in a slow stream. In either case the object is to expose as large a surface of nitric acid to the action of the sulphurous acid as possible. These two bodies, reacting on each other, produce gases which are carried forward to the working chamber. A rather peculiar arrangement is necessarily employed in order to get the nitric acid into the trays. This consists usually of a number of glass siphons, set into carboys of the nitric acid. These siphons convey the nitric acid into another glass apparatus, of which a bell-jar forms a part; the object of the whole being the conveyance of the nitric acid into the interior of the chamber without allowing any gas to escape. The whole affair is by no means simple, and would scarcely suit the manner of working in this country, as, from its construction, it must be very liable to derangement or destruction. Apart from this, it is not very evident what advantage is to be gained by using the nitric acid arrangement. In the first place, there is all the loss from escape, *et cetera*, incident to the manufacture of nitric acid, as well as the cost for labor, *et cetera*; while, by decomposing the nitrate in the burner, this is economized. Nothing can escape uncondensed, as in making the nitric acid every particle of vapor must pass into the chamber. The combustion of the sulphur affords the necessary heat, while the same labor suffices. On the other hand, it would appear at first sight that by this method the amount of nitrous gas necessary for the chamber could be more nicely regulated; but, on consideration, this advantage appears doubtful, for there would be a difference in the quantity passed through, according as the carboys were full, or otherwise, and the taps could, by a little carelessness of the workman, be left running when there was no occasion for them. Such occurrences have taken place to the destruction of the sides of the chamber.

The only part of the nitre system, if it may be so termed, which appears open to objection, or which may be cavilled at, is the contact of the nitric and sulphurous acids at a high temperature, and in consequence the possible decomposition of the nitric acid either into nitrous oxide or nitrogen, both totally inactive, and for the required purpose wholly useless gases. That such a circumstance has taken place is inferred from a fact which occurred in actual practice. A set of burners were worked to their utmost consumption; they became very hot, and required much more nitrate to keep the chamber in proper working order than previously. It would be difficult, in fact almost impossible, to prove the truth of such an opinion; but, nevertheless, it is

possible, and from the above incident probable; but if, for the sake of argument, the truth of this opinion be admitted, this appears, as far as practice goes, to be the only objection to this method of supplying nitrous gas to the chambers.

A Continental chemist, who employed the nitric acid process, saw the nitre process during a visit to this country, and on his return substituted it for the one he was previously employing; by so doing, he effected a saving of one-third of his nitrate of soda. This result could not have been obtained if there had not been some gross error or carelessness in the mode of working by nitric acid. It is possible that little care was exercised in the manner of working, and that, on employing a fresh process, more attention was directed to the subject; in either case the person was perfectly satisfied with respect to the advantages of working by the English method.

As before stated, however, the heat of the burning sulphur effectually drives off the whole of the nitric acid of the nitrates in the pots, leaving sulphate of soda. The nitric acid as soon as evolved comes in contact with the sulphurous acid from the burning sulphur, and is instantly decomposed by it; often, on looking into the ovens or burners, the whole of the upper portion appears filled with ruddy fumes. These, together with the sulphurous acid, pass up the stalk or chimney which conveys them into the chamber, there to react further upon each other, so as to produce sulphuric acid.

It has been attempted to be shown by the detail of the reactions on a small scale that, theoretically, one portion of nitrous gas is capable of converting sulphurous into sulphuric acid almost indefinitely, were it not that certain practical difficulties intervene; for instance, it must be apparent to the student of these experiments, that although one portion of nitrous gas can go on continually carrying the oxygen of the chamber to the sulphurous acid, yet this action must necessarily stop when the oxygen is exhausted. And this is possible, for were a close chamber taken, containing a limited portion of oxygen with the requisite nitrous gas, and the operator kept on introducing sulphurous acid, it would be found, on testing from time to time, that the quantity of oxygen was slowly diminishing, and that at length it had disappeared altogether.

This could easily have been the case with one of Dr. ROEBUCK's close chambers, worked on the intermittent system. To supply this, it is usual at the present day to admit such a constant current of air, that there is sufficient to supply a stream of oxygen over and above what is requisite for the combustion of the sulphur; this finds its way into the chamber, there to effect the necessary change. This oxygen becomes gradually appropriated by the sulphurous acid, as the current of gas keeps slowly moving towards the exit with a regular and constant motion; and as this appropriation never ceases, necessarily the gases on passing out must get poorer in oxygen in the ratio of their nearness to the exit pipe. And this is found to be the case, for if a portion of the gases from this spot are collected, and the slight amount of sulphurous acid and nitric gases removed, the quantity of oxygen in the residue will be found to be considerably less than in com-

mon air. The quantity found differs even in the same manufactory, as no rule controlling the quantity of air to be admitted exists. In fact, it is considered advantageous to diminish it as much as possible, so as not to take up the space of the chamber with a useless superabundance of air. But whether this is judicious or not is matter of opinion; however, the reader is requested to bear in mind that, as before shown, the nitrous gas reaches the exit pipe unimpaired, and passes out with the residual nitrogen, excess of air, carbonic acid, and other matters. This is particularly mentioned, as this part of the subject will be again referred to, with respect to the method now in pretty general use for the recovery of this nitrous gas, and its replacement in the chambers, in order again to commence its labor. This invention of GAY-LUSSAC's is the only improvement of any consequence which has appeared in connection with the manufacture of sulphuric acid for some years; in fact it leaves little to be desired, except the discovery of a material of which to construct the chambers, which, unlike lead, will be indestructible, or at least unacted upon by any of the bodies to the action of which it will be exposed; although, as will be seen in a later portion of this monograph, this problem has been attempted to be solved, its solution has not as yet been successfully accomplished.

Notwithstanding the number of years that sulphuric acid has been, it may be said, a staple manufacture of England, and so much opportunity has existed for studying this process, much misconception as to the true action of chambers exists. The forms, shapes, and other matters in connection with them which have been proposed and built almost exceeds belief—their name is legion; but the prevailing idea, which appears to have actuated many inventors of these ingenious constructions, appears to have been, that the action of condensation in a chamber was simply that of a distillation process; that as the vapor from a boiling liquid in a still or retort condenses on the cold surface of the worm or other refrigerating apparatus, so with a sulphuric acid chamber, the cold walls condensed the acid vapor contained inside. Evidently, with this idea in view, chambers have been built resembling flues; these, having a large surface of cold lead, were supposed to favor the production of the acid by condensing it immediately on its formation. It is related that a clever chemist across the channel constructed a most novel sulphuric acid apparatus. It consisted of an almost fabulous length of lead tube coiled round and round an apartment like a gigantic still worm; that sulphurous acid and nitrous gas were introduced at the highest end; these reacted on each other, the sulphuric acid when formed passing the whole length of the tube, a constant stream issuing from the other end.

It was not stated what length of time this system continued, but certainly on the face of it not long.

It is no uncommon thing to find long lead flues attached to the chamber, for the purpose of carrying off the residual vapors to the chimney. These flues invariably take a most circuitous course, many times longer than the direct route; and as frequently there is no obstacle or other such reason why the flue should not follow the most direct line, one is inclined to

inquire why this latter course was not adopted. If the question were put, the answer would probably be that a steam jet is introduced at the end of this tunnel nearest the chamber from which it issues, and that this length of flue, with the aid of the steam, is expected to condense any vapors not condensed in the chambers. If the product dropping out at the end of this flue be examined, it will very probably be found to be so weak as to be scarcely worth the coals required to concentrate it.

Let the true state of the case be examined. Is it absolutely necessary that there should be a surface for condensation? Is this necessary in all cases, natural and otherwise? Does the rain cloud, which, perhaps, in one half hour will come down in the shape of a heavy shower, require a surface for condensation. If it did, possibly rain would be more manageable; but this watery vapor needs no cold surface; it condenses into water, losing the vaporous and assuming the fluid state, without any assisting cold surface. And if this rain cloud be capable of so condensing, is it not possible for the like physical reaction to take place within a vitriol chamber? But further. Is it not probable, or rather certain, that the sulphuric acid in the chambers never was in the state of vapor. Sulphuric acid requires a heat of 620° to convert it into vapor. The highest point of heat a chamber could attain could be no approach to this; probably the heat of a chamber will not exceed 212° in the hottest part where the gas enters. Is it not possible that every atom of sulphuric acid produced passes from sulphurous acid gas to liquid sulphuric acid at once the instant it is formed—that the chamber is filled with myriads of these newly-formed particles—that these float about, and, like globules of running mercury, they gradually coalesce with each other, until they at last form a particle like a rain drop, sufficiently heavy to resist the sweeping influence of the currents which exist in the chamber; and that, finally, this drop falls into the acid on the floor of the chamber. Although it is impossible to see the process, and so prove the truth of this opinion; a very good inference of its justness may be drawn from an experiment which was tried on a chamber. A strip of lead about three inches wide was attached to the inner side of a chamber, in such a manner that it resembled a gutter or spout in an inclined position, one side of this gutter being formed by the chamber side, the other by the strip. This was placed about from two to three feet above the surface of the acid in the chamber, and was about nine feet long. In consequence of this position, the whole of the acid which formed or condensed on that side of the chamber above the strip would flow along it, and be carried by a small tube passing through the wall of the chamber into a vessel placed on the outside to receive it.

If the liquefaction of the acid took place almost wholly on the side of the vitriol chambers, a pretty rapid current of acid must have flowed along this arrangement, but this was not the case; instead of, as might have been expected, a constant stream passing along it, nothing more than isolated drops issued, probably at the rate of six drops per minute, an utterly insignificant quantity, when compared with the amount

of acid which must have been formed within the space over which this strip had the command.

In fact any observant manufacturer must, after a little attention to the subject, come to the conclusion that such is the case; that condensation goes on chiefly within the space of the chamber, although a small portion may condense on the walls; for when the acid particles are floating about in the chamber—driven hither and thither by the various currents which must exist—some must become attached to the sides and flow down into the acid already at the bottom, adding to the amount already formed. But the argument remains that all the acid is not brought to the liquid state by this means; that, in fact, the quantity thus formed bears a very small relation to the whole.

To many this will be already palpable, but evidently not to all, inasmuch as these strange abortions of chambers are not by any means as yet extinct, but still remain a testimony to the ignorance of many of our manufacturers. It must be apparent, that if anything more than the usual average amount escapes from the chambers, either they are badly worked or overworked. If the first should be the case, more attention must be directed to them to find out the error. If the second suggestion be correct, then, as the chambers have more material introduced into them than they can properly work, the amount of sulphur usually burned must be decreased, until the maximum amount which can be burned with a beneficial result is found. It needs little argument to prove, that the working space included in a tunnel could have been included in the chamber at much less expense.

The introduction of steam into the chambers has been already mentioned. Previously to the use of this reagent, the water on the floor of the chamber had all the work to do; every particle of the sulphuric acid and nitrous compound was compelled to pass in to the water from whatever portion of the chamber it was formed in order to be decomposed. The interior of one of Dr. ROEVER'S chambers, or any other chamber worked in the same manner, while in action would have been a pretty sight; the reactions must have taken place consecutively, as described in a preceding portion of this article when treating of the theory of the process. Every particle of sulphuric acid formed must previously have passed through the solid crystalline stage. The interior walls of the chamber must have been each time more or less coated and incrustated with the beautiful snow-like crystals, while the whole interior of the chamber must have resembled a snow-storm in an amber-colored atmosphere. The first manufacturer who introduced steam into his chambers did but exchange a beauty he could not see for a solid reality he could well appreciate. He introduced a most beautiful invention, which not only increased the production in the same chamber-space, but altogether simplified the operation. Instead of, as before, each equivalent of the double compound waiting to fall down into the cold liquid which covered the floor of the chamber in order to be decomposed, leaving, probably, a large per centage of the nitrous constituent behind; the bodies now never assume the solid state but on extraordinary occasions, and then only through

neglect. The whole of the reactions take place in a warm wet atmosphere, where everything is favorable to the intended purpose.

Sulphuric acid, when tolerably concentrated, has a tendency to combine with nitrous acid, forming a definite compound to be treated of hereafter; but unless the acid be concentrated, more so, in fact, than it is usually found in chambers, this compound is very unstable in the cold; heat it and the nitrous constituent flies off.

In a chamber worked on the old plan a great quantity of nitrous gas must have remained in the vitriol, causing a great loss of this body—the most expensive material the manufacturer employs. On the contrary, in the chambers of the present day, each particle of acid as formed must, if sufficient steam be present, be of such a density or strength and temperature as to be incapable of carrying down, and thus removing from its proper sphere of action, any of the nitrous bodies present. Again, in the old plan of working, the nitrous gas was only liberated at the surface of the liquid at the bottom of the chamber. Now, peroxide of nitrogen— NO_2 —the body into which the nitrous gas would become changed the moment after its liberation, coming in contact with the oxygen in the chamber, is a heavy gas, heavier than common air. It can be floated about and poured from vessel to vessel like carbonic acid. This then, on its being set free, would float about on the surface of the liquid, running the risk of being rapidly absorbed; whereas its sphere of action lies amongst the lighter sulphurous acid, on the upper portion of the chamber, to which point this NO_2 could only be conveyed by diffusion, or be carried up by getting entangled with the upward stream of gases emanating from the tube which conducts the sulphurous acid into the chamber. In the present system, whenever a particle of this peroxide or quadroxide of nitrogen meets one of sulphurous acid a reaction commences. Now there is no necessity for a descent to the bottom of the chamber; water, in the shape of vapor, pervades every part of the chamber; and as quickly as the crystalline combination forms, if it does form under these circumstances, it is as quickly decomposed. The resulting sulphuric acid falls, but the nitrous gas forms a second combination, and is then again ready to perform its purpose the moment it comes in contact with another particle of sulphurous acid. When carefully considered, it will be understood that it is not too much to call the introduction of steam into the chamber a great invention. It is not difficult to imagine how slow the process must have been in the old chambers when compared with the rate at which it proceeds now, and what enormous advantages manufacturers at the present day are possessed of over their predecessors.

Much difference of opinion exists as to the proper density at which the acid should be kept in the chamber, or rather what is the maximum density to which it may be allowed to rise? All manufacturers are aware that it is to their interest to keep up the strength of the acid in the chamber to the highest point possible, for by so doing there is a saving of fuel in the concentration. A writer has lately stated, on the authority

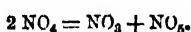
of an eminent manufacturer, that it is impossible to keep the vitriol free from nitrous gas if a density of 1.45 or 90 degrees. Twaddell is exceeded; while again in KNAPP's *Technology* it is stated, that the maximum density of 1.585, or about 112° Twaddell, should not be exceeded. A considerable margin exists between the two statements, but in such matters as these, which are not found capable of absolute and precise proof, the only course to be pursued is to take for a guide a near approximation to some recognized authority, or perhaps better, to be guided by the result of practice. A set of chambers now at work are kept at a general strength of from 110° to 112° Twaddell. It is not observed that more than a trace of nitrous gas is absorbed, except occasionally, and these instances may invariably be traced to either a slackening or a total cessation of the current of steam, either from the carelessness of the workman or by accident. In either case the pressure of steam has become so low that little or no watery vapor is being thrown in. Perhaps there is no manufacturer who has not at intervals found his chamber acid so highly charged with nitrous gas as to slightly effervesce when poured with violence from one vessel to another; in fact, it is not an extremely rare occurrence, under some circumstances, to find it perfectly green, from holding a large quantity of peroxide of nitrogen in solution. If, when this takes place, strict inquiry be made, it will be found, that such a state of things results from the chamber having been left for some time, possibly for hours, without steam. This point is worthy the manufacturer's attention, as it largely concerns his profits. The chambers, as at present constructed and worked, are not calculated to work on the old plan. As has been stated before, the steam materially quickens the process, and is the means of much more acid being made in a chamber than could be made were it worked on the old plan. When without steam, the excess which the chamber is not able to convert must pass up the chimney, being a loss of its value as well as risk of nuisance or damage. And not only does this occur, but nearly all the nitrous gas which is dissolved in the vitriol flies off when it becomes hot in the concentrating pan, to no purpose but to annoy the workman and surrounding neighborhood. Such a state of things is not an imaginary case, but a fact, as nearly every vitriol-maker can testify, and that to his material cost.

PAYEN gives a method for economizing this nitrous gas passing from the chamber dissolved in the vitriol. This he proposes to do by passing a stream of sulphurous acid over the surface of the vitriol while being concentrated; the sulphurous acid liberates any nitrous gas or decomposes any nitrous compound, and becoming mixed up and absorbed into this sulphurous stream, is carried into the chamber. The apparatus for effecting this purpose, though ingenious, renders the process of concentration too complicated, in fact, leaving a doubt whether the economy effected by its use is not more than balanced by the inconvenience entailed by its employment. Most manufacturers have a very wholesome fear of what is called a break down, and the general want of stability which this apparatus appears to have is not likely to make it a favorite.

The Recovery of the Nitrous Gas.—The reader will no doubt have borne in mind, that whilst tracing out the reaction of the chamber it was possible to follow the sulphurous acid until it was completely converted into sulphuric acid, and that during this process the whole of the free oxygen of the chamber may become exhausted, but that, nevertheless, the nitrous gas still remains the same. This gas does not enter into, neither does it give up, any essential part of itself to the vitriol; its removal is only on account of its passing off with the current of useless nitrogen and other gases, and when removed it still possesses all its active properties, but diluted and incommenced with a quantity of gas of no value. Many have been the attempts to prevent this loss, and to bring this nitrous gas back into a useable form, and this idea has formed the principal feature in many patented improved methods of manufacturing vitriol. Perhaps the most successful worker in this direction was GAY-LUSSAC, the celebrated French chemist. His process, which was patented in this country, is at present in use in several works, and is found to be perfectly practicable, and to answer well the desired end.

In order that the reader may have a clear general idea of the invention, it is necessary to draw on the imagination a little. Let it be supposed possible to construct a filter through which to pass the unaltered air—nitrogen, trace of sulphurous acid, and nitrous gas—which forms the current constantly passing from a chamber; let this filter have the property of retaining the last-mentioned gas, and of letting all the others pass on to the chimney. When sufficient material has been collected on this filter, let it be possible to remove this retained material and to introduce it into the chamber again, there to renew its former labours, and a view is obtained of GAY-LUSSAC's invention. It has been shown that sulphuric acid, when tolerably strong, possesses the power of absorbing, retaining, or uniting with certain of the lower oxides of nitrogen. Most if not all works on chemistry treat more or less of these combinations, although not much appears to be known about them. GAY-LUSSAC studied them to a considerable extent, and perhaps gave the most just account of them; to this study manufacturers are doubtless indebted for the invention. The formulæ of these compounds are given very differently, arising no doubt from the difficulty of separating the different combinations formed, and then of analyzing them. But they appear to be generally considered as compounds of one, two, or more atoms or equivalents of sulphuric acid and nitrous acid, NO_2 . Some view them as compounds of sulphuric acid and peroxide of nitrogen, NO_4 . But whatever the composition, it is certain that peroxide of nitrogen forced into, or rather passed through strong sulphuric acid, is retained by this acid, and the body in question is formed. This is the principle of the process. It may be performed in miniature as follows:—First, fill a potassa bulb apparatus, or a small Woulfe's bottle with strong sulphuric acid—this is for the absorption—connect this with another Woulfe's bottle containing copper turnings; let a safety or tube funnel be put through a cork in the second neck of this bottle, the other neck being con-

nected by a short length of tube with the absorbing bottle, which also must have two orifices, one of which is to receive a short length of tube leading from the bottle just described to the bottom or lower portion of the sulphuric acid. The second neck must be connected with a suitable aspirator gas-holder. When all is complete, pour a little diluted nitric acid through the funnel on to the copper clippings, having previously set the aspirator at work, drawing a stream of air down the funnel and through the sulphuric acid; after a while, when the action appears to diminish in intensity, pour on a little more nitric acid, still keeping the aspirator at work, drawing the whole current of gases through the sulphuric acid. This must be kept on until the sulphuric acid appears to be becoming saturated; this is indicated by red fumes passing through in quantity. The apparatus may now be disconnected. The rationale, which has been partly described before, is simple. The nitric acid acting upon the copper produces nitric oxide, NO . This, immediately on coming in contact with the oxygen of the current of air which is passing through, becomes converted into peroxide of nitrogen, and this is absorbed by the sulphuric acid, forming a compound with nitrous acid, another with nitric acid, being formed at the same time probably as follows:—



In this experiment the imaginary filtration has been really effected. Excess of air, nitrogen, *et cetera*, have passed on while the nitrous compound has been retained; thus one-half the problem is solved. When the apparatus has been disconnected, empty the bulb apparatus or bottle, as the case may be, into a convenient glass vessel, and pour into a beaker glass a volume of hot water, twice the bulk of the nitrous vitriol; pour this nitrous vitriol slowly into this hot water—a copious evolution of nitrous gas will ensue; in fact, if nearly boiling water be employed, almost all the nitrous gas absorbed will be again given off; a small portion will remain, having formed nitric acid as follows, supposing the liquid to be a compound of sulphuric acid and nitrous acid:—



This NO_2 becomes peroxide of nitrogen in contact with the air. The above reaction has been given before in connection with the chamber reaction, but still it is scarcely out of place.

This experiment then is exactly a representation on an experimental scale of GAY-LUSSAC'S invention. Sulphuric acid forms his filter, by which he separates the valuable nitrous gas from its useless companions, although not exactly in the manner just given. Columns for the condensation of gases are well known pieces of apparatus in all chemical works. They are usually tall hollow towers, constructed, according to the purpose for which they are to be used, of stone or lead. They are filled with pieces or lumps of any suitable material which offers a large surface, and at the same time are not acted upon by the acids or acid gases, or other corrosive substances with which they have to come in contact. Coke offers many points of advantage

in this particular, as it is acted upon in the cold by scarcely any chemical body; and it offers this additional advantage, that while offering more surface than perhaps any other material at all adapted to the purpose, it is at the same time very light. The column to be employed for the absorption of these nitrous gases is filled with coke, and by means of suitable contrivances, to be detailed hereafter, it is kept constantly moistened with a small stream of strong sulphuric acid, which is continually run on to it. The gases from the chambers are made to pass up or through this column or tower on their way to the chimney; and in order to do so, they have to wend their way through the many thousand passages and openings formed by the interstices existing between the pieces of coke. Thus they are split up into numerous streams, and have to come in contact with many hundreds of feet of surface wet with vitriol before they arrive at the exit pipe. The apparatus is built of such size and proportion that the gases in their course upward are brought into contact with sufficient sulphuric acid to absorb the whole of the nitrous gas contained in them. The acid containing the absorbed gas is collected in a proper reservoir or receiver, placed at the bottom of the column for its reception, from thence, as will be seen hereafter, to be removed, in order that it may be decomposed in such a manner that its nitrous constituents may be again used.

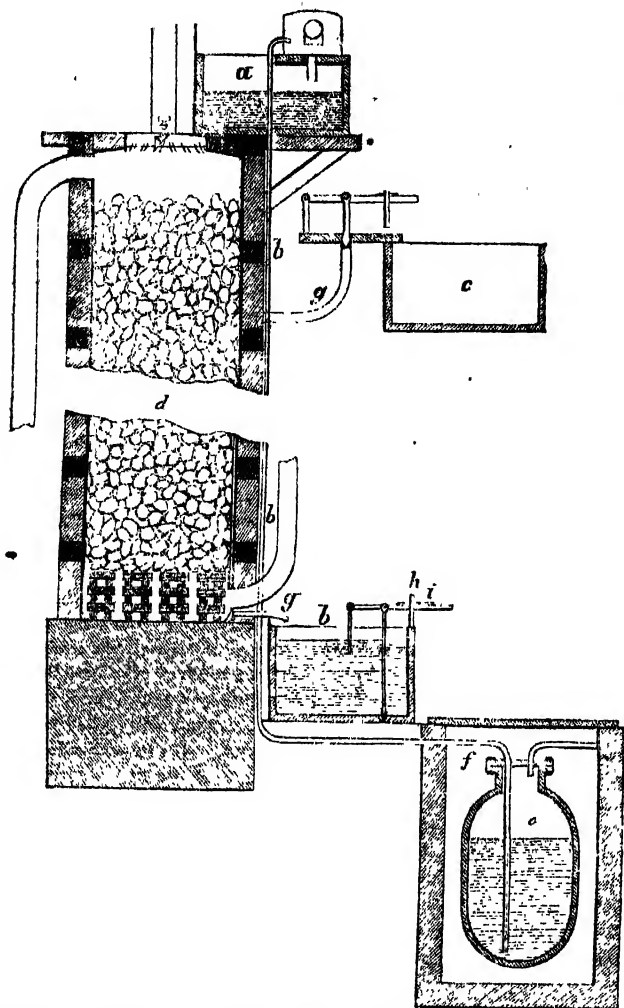
This apparatus seldom or never works well when applied on the small scale, as, for instance, when applied to one or two small chambers. This is a practical difficulty which, perhaps, in the hands of a careful and determined person, might be got over. It has been applied on a small scale at several works, and has been given up. On the other hand, several vitriol manufacturers on a large scale who use it, speak very satisfactorily of its performance. In some cases, by its employment, the consumption of nitrate of soda has been reduced from one-tenth the weight of the sulphur employed to one-twentieth—in fact, to the extent of one-half of that previously used. This is certainly a very good result.

The dimensions here given are those of an apparatus which is applied to a set of chambers, in which an average of eighteen tons of sulphur are consumed or converted into sulphuric acid per week of seven days. The apparatus is seen in Fig. 582. It consists essentially of the column or tower itself, three cisterns for holding or containing vitriol—*a*, *b*, and *c*—together with a large close cast-iron cylinder, *d*, employed in raising the vitriol to be used for absorption from the surface to the upper cistern at the top of the column, and also for removing this when nitrated or saturated with nitrous gas. The tower cannot be more appropriately described than as a tall cylinder of lead, five feet diameter, and thirty feet high, supported, like the lead of the chamber, by a suitable strong wooden framework. This leaden cylinder is completely closed in at the top, and stands in a suitable leaden dish or tray at the bottom, of such a depth that it always contains vitriol enough to lute it, and so prevent any escape of gas. The thickness of the lead is from a quarter to half an inch—some manufacturers preferring to use the thinner variety from motives of economy, while others, in order

to insure absolute safety, prefer to use half-inch lead. This cylinder, as stated before, and as shown in the drawing, is filled almost completely with large pieces

of coke. The quality of this coke is not by any means a matter of indifference: it must be in large firm pieces, for if it is either in small pieces of a rotten or soft

Fig. 582.



variety, it must be rejected; for, if small, sufficient space will not be left between the pieces for the proper passage of the gas, but will choke up the whole apparatus: besides the weight of the coke in the upper portion of the column will crush that near the bottom, and a similar result will follow. It will be, perhaps, well to mention, that if quarter-inch lead is used in the construction of the column, it would be well to line it with thin fire-tiles. These must be applied simultaneously with the filling in of the coke, as it would be impossible to hold them in their places otherwise; they must be placed as close as possible to the lead, and pressed to it, and held in their places by the coke pressing against them. This precaution of brick lining is necessary to prevent—what might otherwise occur—the cutting of the lead by the sharp edges of the coke; for although the column may be quite full at the first, yet, after a while, it will be seen that the whole mass

has subsided some inches, has in fact settled down, and were the tiles not in their places to protect it, it is possible that a sharp edge of coke might cut a slit in the lead.

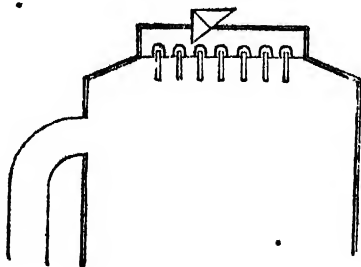
It is necessary to have some arrangement at the bottom of the column by which the gases from the chamber can have unobstructed entrance, for were the coke at once thrown in, without some contrivance for this purpose, it would fill up the entrance pipe, and prevent or nearly so, the entrance of the gases. A very good arrangement for this purpose may be made with fire bricks, which are almost unacted upon by acids. The lower part of the tower or column, to a few inches above the entrance for the gases, is filled in with these fire bricks—arranged in a systematic manner; in fact, built up in the most open and loose manner possible, so as to allow the greatest amount of inlet to the gases. The coke is piled above this. By this arrange-

ment the gases have all but a totally uninterrupted entrance; they rush up through the wide spaces left by the brick, and from thence divide themselves amongst the numerous passages which they find between the coke.

At the top of the column is placed the cistern containing the vitriol, which is run down it. Care should be taken, in the construction of an apparatus of this kind, that the timber work is sufficiently strong to bear the rather heavy weight of this cistern; but this, of course, is what few would overlook. Inserted into what may be called the roof of the column is a device for spreading the vitriol over the whole surface of the coke. In fact a good deal depends upon this, for were the vitriol run on just in one spot, it might possibly find its way down in one small stream not capable of taking up the nitrous gas, in consequence of its having little surface. KNAPP recommends this spreading to be effected by a series of cones placed within each other; these cones, which, as might be supposed, are constructed of lead, have each the apex removed, and the open ends of the whole system are placed immediately under an orifice in the roof of the column. The vitriol is made to enter these open ends in flushes; it rushes over the surface of the different cones, and finds its way to the interior, wetting the coke with a series of concentric circles of sulphuric rain. This will be understood by referring to Fig. 581.

A method which answers tolerably well is shown in Fig. 583. This is an arrangement actually in use. It will be better understood by supposing a broad flat dish, about two-thirds the diameter of the column

Fig. 583.



itself, to be placed on the roof of the column. Into this are inserted a number of tubes—about twenty or thereabouts; these tubes protrude both down into the column, and for a shorter distance up into the dish. The under portion of the tube can be bent, so that the stream which it delivers can be directed to any point desired; for instance, let the whole area of the column be mapped out, and twenty different equi-distant spots be marked; a tube is directed over each of these spots, so that when in action the coke is wetted in twenty different places, in this way increasing the chances of the whole body of it getting thoroughly moistened. Whatever mode of attaining this end may be adopted, the use of an oscillating box, or what the workmen, perhaps more expressively than elegantly, term a *tumbling box*, is almost absolutely requisite; for, in the

last-described scheme, without such an adjunct the spreading would be very inefficiently performed. The stream of vitriol which is run down a column of this description is, comparatively speaking, very small; and when this comes to be divided into twenty separate streams, they must naturally become very much less; so much so, in fact, that the chances are, that unless the ends of the tubes which project into the basin are exactly of one level, which practically is impossible, some three or four which happen to be the shortest, will take almost the whole of the stream. This casualty is put out of the question by the use of the oscillating box, the action of which is to deliver a comparatively large body of fluid at intervals, and this from a small stream. It is easy to see that each time the box oscillates and delivers, say a quart of fluid, the height of the liquid in the basin suddenly rises, and then immediately subsides, enough fluid having been delivered to furnish a current for each of the twenty different tubes.

It would, perhaps, be well here to describe the construction of one of these oscillating boxes, notwithstanding their being well known, and their action thoroughly understood. It is an old invention, and has been figured and described in many works on chemistry. It is constructed of a shape similar to that of two cones fastened together at the base and sectioned, with an axis connecting the apices; this will be seen by referring to Fig. 584. This apparatus, as depicted, is a diamond-shaped box, open at the two upper, and closed at the two lower sides. The box is divided into two by a partition, *a*, in the centre, and the whole is mounted on an axis, *b*, on which it can oscillate. It works, in this manner, one of the two spaces caused by the division, presents itself to the tap of the cistern, or other vessel, whence a small stream is issuing. It will be seen, by examining the figure, that the fuller one of these spaces becomes, the more to that side must the centre of gravity incline, until at length this centre of gravity gets thrown so far beyond the axis, as to overbalance the empty side of the box. When this occurs, the whole of the liquid which this division contained is emptied out suddenly, and the other side presents itself for filling; the apparatus taking the position indicated by the dotted lines. Of course, in a short time, this side becomes full, when a reverse again occurs, and so on as long as there is sufficient liquid to keep it in motion.

Fig. 584.



Another point of some importance in connection with the economizing powers of this column, is the regularity of the stream of acid which runs down. If the tap of the cistern, whence the acid flows, is set to a certain speed at the commencement of the space of time during which the acid is to last, it is certain that it will not run at the same velocity when the cistern is getting nearly empty; nor, according to the proper physical law which controls these matters, will it run with the same force during any two portions of time. According to the law, the rate decreases as the square root of the depth; or, to take a practical and easily understood illustration—suppose it is a cistern three feet deep, then whatever the

number of quarts, gallons, or other volumes per minute at which it runs, it will be delivering exactly half that number when the cistern has lowered to nine inches deep. Thus at one time there would be running down exactly half the quantity as at another; at one period probably supplying the apparatus with more vitriol than is necessary to take up the nitrous vapors, and at another time not giving it sufficient acid, thus allowing a valuable substance to escape.

This idea appears to have struck either the original inventor, or an early employer of this process; for in KNAPP'S *Technology*—which appears to be the only book in which a description of this process is inserted—a drawing of a method of obviating the defect is given. It is there proposed to employ a closed cistern, in principle resembling a bird's drinking fountain, where water can only be obtained by replacing the space occupied by it with air; and to cover this cistern with a top constructed of thick lead, supported in the interior by iron rods, sheathed in lead, to protect them from the action of the acid. When working, this apparatus must have had two alternate currents passing through the tap, one current of air into the receiver, to supply the place of the acid flowing out of it into the oscillator.

Several objections to this plan present themselves. In the first place, such a closed cistern must have been very inconvenient to work, in consequence of the increased amount of manipulation; for it was necessary to have an orifice in the cover through which to fill it. This aperture required to be made perfectly air-tight when the cistern was filled; for if this was not done, the whole principle involved became nugatory. Again, the construction of such a receiver must have presented many difficulties, not to speak of the great liability to leakage in the cover and other parts of the cistern. Besides, when the cistern leaked, a great portion of the cover would require to be removed, in order to admit a workman to repair it; the cover itself would also have to be repaired, taking up much time, during which the whole apparatus would be inoperative.

Many other objections present themselves on examination, but are scarcely worthy of remark, inasmuch as no cistern of this construction appears to be at work at this time, at least in this country.

An apparatus which answers the desired end very

well has been applied; and it has none of the objectionable features just described; it is shown in section in Fig. 585, where *a* represents the cistern containing the supply of acid. Adjoining this cistern is a circular vessel of lead, twelve inches in diameter, and of the same height as the cistern. Between these two, and from the bottom of each pro-

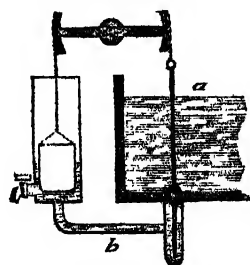
ceeds a tube, *b*, which forms a passage between them. This tube is not a whole piece of tube, neither does it take the shortest course between the two vessels, and

this for a reason which will be presently shown. The upper portion of the pipe opening into the cistern is of a conical shape, and into this is fitted a conical lead plug, which has been cast on a long iron rod, and turned up in a lathe very smoothly and with great nicety, so as to fit very accurately into its seat, the conical mouth of the tube just mentioned. This plug, as shown in the drawing, has the iron rod, which forms its stem, prolonged below the plug proper some eight or ten inches. This portion, as well as the upper, up to within an inch or two of the hook at the top, is coated with lead. This coating must be done very accurately, to insure the exclusion of the acid from the iron rod. This is best done by pushing the rod through a lead tube of the proper diameter, and fusing the extremities of the upper and lower portion to the plug proper by means of the blowpipe jet, described in that portion of this article which treats of the construction of the chambers. The lower length of the rod moves in the straight portion of the tube below the cistern, and is for the purpose of preventing the plug getting out of its seat, as well as for accurately guiding it in.

Within the tall cylinder before spoken of hangs a leaden bucket, for so it may be most appropriately called; the rim, or upper edge of this bucket, has an iron ring inserted into it, for the purpose of keeping it in its proper shape. To this ring are attached three iron chains, not unlike, in thickness and general appearance, to dog-chains. These chains are attached at a short distance to a single chain, which hangs in the centre of the cylinder. The upper end of this chain is in its turn attached to one end of a lever, moving freely on its axis, situated at the middle of its length. To the other end of the lever is attached another short length of chain, connecting the end of the lever with the hook at the extremity of the plug. This lever has semicircular pieces of iron attached to its ends, over or on which the chains rest, in such a manner that the plug and bucket have each, as near as may be, a true vertical motion, so that the plug may descend exactly into its seat, and that the bucket may move up and down precisely in the centre of the cylindrical vessel. This cylindrical vessel has the delivery tube fastened to it, and the tap from which the stream flows attached to it again.

In order to work effectually, imagine that the apparatus is newly attached, and has not been used before, and that this is the first trial. Let one imagine that the plug has been inserted unattached to anything else into its seat, and also that the cistern is full of vitriol; also determine that the vitriol shall run out at a pressure of some six or eight inches—vitriol pressure, not water. To do this, let the bucket hang down in the cylinder some six or eight inches from the bottom; attach the chain to the lever, and then attach the plug by means of the chain to its other end. In both cases this should be done so that the lever remains in a horizontal position; then let the bucket fall to the bottom. The result of this will be that the plug will be drawn from its seat, and the vitriol will run from the cistern into the cylindrical vessel through the communicating pipe. Now, watch

Fig. 585.



the action of the apparatus as the vitriol rises in the cylinder. As it does so the bucket will rise. Now, as first said, this bucket is fastened to one end of the lever, while the plug is fastened to the other—in point of weight the plug is the heaviest. Under these circumstances it naturally follows, that as the bucket ascends the plug descends, until at last the bucket ascends so high that the plug falls into its seat, and effectually closes the passage. If allowed to remain, and if the plug fits well, the liquid rises no higher in the cylindrical vessel. But if the delivery tap be opened the liquid in the cylinder will be seen to subside, the bucket descend, and the plug be lifted from its seat so high that it allows just so much liquid to pass it as is running out through the tap, whatever this quantity may be.

Thus, on examining the action of this apparatus, it will be found that it allows the cistern to be run almost empty at precisely one pressure, either six, eight, or any number of inches, thus obviating the misjudgment of the workman, or, what is probably oftener the case, the total neglect of its rate of running. A careful workman, from constant practice, soon learns to set the tap so that it shall run many hours without altering; he has only to notice the time required to run so many inches out of the cistern, it having a gauge with inches marked on it for this purpose; from this he can easily calculate, from the depth of the cistern, whether it will last out the required length of time. If the rate of running is not correct, it must be altered less or more accordingly. As this apparatus is not patented, it may probably find other applications.

Having now described the mode of running the acid down the column, let attention be turned to another and previous portion of the subject—the manner of placing it in the cistern. It is well known, and is a matter of no little regret, that as yet there is no real acid pump. Weak vitriol can be pumped with a pump of the ordinary description—the barrel formed of lead, the valves and all the flexible portions being formed of caoutchouc. But this latter body, and every other body which serves its purpose for ordinary liquids, is destroyed in a few hours, when placed in strong sulphuric acid even when cold. Such being the case, another contrivance is adopted—a very useful although not a very new one, it being at least as old as the chemist's eductor, used in analysis for washing precipitates. This apparatus, as is well known, enables one to drive out a rather forcible though small current of water by atmospheric pressure applied on the surface of the water contained in the bottle. This is effected by closing the neck of the flask or bottle employed with a cork through which two tubes pass, one of which descends to the bottom of the flask below the surface of the contained water, while the other merely protrudes below the bottom surface of the cork. By means of the mouth, air is forcibly compressed within the bottle; this, in its efforts to escape, drives the water before it in a stream; and this is the principle of the apparatus by which the vitriol is elevated. A large cast-iron vessel, *e*—Fig. 582—replaces or rather represents the washing bottle. This vessel is for con-

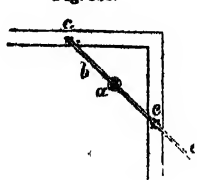
venience placed in a walled cell or space dug in the ground, and is made of such dimensions that it will hold rather more than the cistern it is destined to fill. It is formed not unlike a soda water bottle, this shape being the strongest, the lower and upper ends being rounded, the latter having a flanged neck cast upon it; this being about one foot wide. This flange has a number of bolt holes cast in it, corresponding to a like number of bolt holes in the lid. The lid has two perforations cast in it through which two two-inch diameter pipes can be passed and be secured, one of which pipes, as in the case of the wash-bottles, passes to the bottom, or nearly so, leaving a space of merely two or three inches; the other pipe merely passes through, terminating beneath the lid. Perhaps the best method of making a secure joint between this lid and the vessel flange is to insert an India rubber ring of such a size that it will lie within the circle of bolts; the ring being thus placed, the bolts are put in and screwed up tightly, thus compressing the elastic washer, and forcing it to fill up every crevice, so as to be effectually air-tight. The whole of this description will appear much clearer on referring to the figure—Fig. 582.

The drawing which accompanies this is scarcely complete, inasmuch as one cistern has been left out; this has been done purposely, so as not needlessly to complicate the figure. In order to explain the drawing the reader must consider himself working the apparatus. In the first place, suppose the iron cistern, *e*—Fig. 582—to be filled with vitriol of the density 1.750, or 150° Twaddell, this being the strength of vitriol to be used in the absorption of nitrous gas. At this moment it does not matter how it was filled. By means of a powerful air-pump, a strong pressure of air is forced on to the surface of this vitriol, driving or forcing it up the pipe, *f*, into the cistern, *a*, which it fills. From this cistern it runs, as has been already described, into the column, where, after traversing the coke with which it is filled, it runs into the dish-like vessel in which the column may be said to stand. From this it runs by means of the pipe, *g*, into the cistern, *b*; it is now by this time saturated, or nearly so, with nitrous gas, which it has gathered during its passage down the tower. From this cistern, *b*, it is once more run into the iron underground vessel; the air-pump is once more put into requisition, and it is forced from this vessel into the cistern, *c*, there to be reserved and run off as wanted, to be decomposed in the chamber.

As before stated, the cistern for the raw vitriol is not included in the drawing, but, as it is only a copy of the one at the foot of the column which is represented, a description of the one will serve for the other; it will also suffice to describe how the nitrous vitriol is conveyed from the cistern, *b*, into the cistern, *c*. It will be seen that from the bottom of the cistern, *b*, a short tube proceeds, which immediately joins on to the main pipe or artery, *f*; into the conical mouth of this pipe which opens into the cistern, a plug is fixed, which plug, like the one already described, is simply a conical boss or mass of lead cast on to the end of a sufficiently long rod of iron, and turned in a lathe to a fine surface, so as to make as accurate a fit as possible, the shank being sheathed in lead so as to

preserve it. The upper end of this rod is split, so as to embrace a lever, to which it is firmly attached by a hinge-like joint. This will be better understood by referring to Fig. 586, where *a* is the plug, as already described; *b* is the lever to which it is attached; *c* is a joint at one end of the lever, and which serves as a fulcrum; *d* is the handle at the other end of the lever; *e* is a guide in which it works, and which confines its movements to a simple vertical motion. The plug apparatus is fixed, as shown in Fig. 586, across the corner of the cistern. Now, to get the vitriol in *b*—Fig. 582—into the iron vessel, the workman simply

Fig. 586.



lifts the plug at the corner of the cistern; this he does by a sudden jerk, after loosening a little piece of apparatus, to be hereafter described, and which is for the purpose of keeping the plug in its place and preventing its rising when the pressure comes on to its under surface. Immediately he lifts

this plug the sulphuric acid proceeds to run down this short tube into the main artery, and thence into the cylinder, driving out the air through a tap placed for the purpose. Immediately the cistern is empty, the workman by a forcible thrust fixes the plug in its seat, and for fear the pressure should force it out, he proceeds to fasten it down, as shown at the cistern, *b*—in Fig. 582—where in the upright, *h*, a number of holes are shown; into one of these a cotter, or piece of round rod iron, is thrust; then between this cotter and the lever he drives in the wedge, *i*, thus effectually preventing the rise of the lever, and consequently firmly holding the plug in its place. As soon as this is accomplished, he proceeds to set the air-pump in action, which air-pump injects air on to the surface of the vitriol; and when sufficient pressure has accumulated, the acid gradually flows along the horizontal pipe and main artery, *f*, until it arrives at the pipe, *f*, along which it proceeds, eventually emptying itself into the cistern, *c*, the air-pump being kept in action until all the vitriol is forced out of the cylinder, and a small portion of air following indicates when this has taken place.

The next part of the process is the conveyance of raw vitriol into the cistern, *c*. The details are precisely similar to those already described. Let the reader imagine another cistern precisely like cistern *b*, a perfect copy plug included, which said cistern has a short plug connecting it with the main pipe or artery, *f*. As in the case of cistern *b*, the workman removes the plug, and allows the vitriol to flow into the iron cylinder as before; when he has done this he proceeds to take measures for projecting this charge into the cistern, *a*, at the top of the column.

On the branch pipe leading to the nitrous vitriol reserve cistern, *c*, a plug apparatus will be observed. This is for the purpose of closing this branch pipe while raising the raw vitriol, and is taken out when the nitrous vitriol is being pumped up. It is scarcely necessary to remark that when the nitrous vitriol flows through this branch pipe, it naturally issues at the open end over the cistern, *c*, such being the lowest. In order to prevent

the raw vitriol taking the same course, the workman firmly inserts and fastens down this plug; and, when the acid to be used for absorption has filled the iron vessel, he sets the air-pump in motion, and the vitriol rises up to and flows into cistern *a*.

In consequence of the height of the column of liquid rising from the bottom of the iron vessel to the upper edge of the cistern, *a*—a space of nearly thirty-eight feet—and of its superior gravity, a pressure is exerted approaching to thirty pounds on the square inch. Hence it will be apparent that the cylinder and its appendages must possess a considerable amount of strength. It is usual to have them cast two inches thick in the sides in order to withstand this weight.

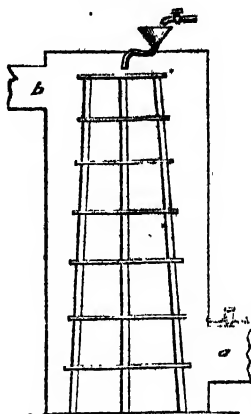
The air-pump used in this case, and which has been so often mentioned, is constructed on the model of an iron furnace-blowing engine, and differs from it only in dimension. The cylinder of this pump may be about eight inches diameter, the length of stroke being twelve inches, and it makes about fifty strokes per minute. It has a rather heavy fly wheel attached to it, to steady its action. This is necessary on account of the great resistance it has to overcome at the end of each stroke. It is necessary that the piston should fit very accurately, and that about the pump and the fittings generally great care should be taken to insure perfect freedom from leakage.

The quantity of sulphuric acid used in the absorption is rather variable, some manufacturers being more successful in this respect than others. Many who employ this apparatus recommend one-third of the make to be run down every twenty-four hours. In this case, for every hundred tons of acid made per week, nearly five tons would be run down per diem. One manufacturer finds in practice that about four hundred gallons, or seven thousand pounds, run down the column every twelve hours, will absorb the nitrous gas from a set of chambers which are converting eighteen tons of sulphur weekly into sulphuric acid.

To utilize the nitrous vitriol it is necessary to liberate the nitrous acid it holds, either within the chamber or contiguous to it, and in presence of the sulphurous and other gases entering it. Simple dilution with water effects this, as explained at page 1033. Still its practical working at first was found somewhat difficult, and much ingenuity has been expended in improving this part of the process, but still something further remains to be done before it can be considered perfect. The original inventor gave a method which, though theoretically almost perfect, was, unfortunately, not quite so, practically. It consisted in exposing the nitrous sulphuric acid in thin films or sheets to the action of the sulphurous acid which issued from the sulphur ovens. By this he proposed to liberate the nitrous gas, and in part he did so. The apparatus is shown in Fig. 587, which represents a sort of leaden column. Within this column a series of horizontal shelves or partitions are placed, which almost fill up the whole of the area; a funnel, furnished with an S tube, is inserted into the roof, and through this the nitrous sulphuric acid is poured on to the shelf immediately beneath. It runs from this first shelf on to the next one, and so it proceeds to the bottom, in exactly an opposite direction to that

pursued by the sulphurous acid current, fresh portions of which it meets at every point of its progress downwards. The funnel tube is of an S form, for the purpose of preventing any of the gas escaping, a quantity of the liquid being retained in the curvature of the tube sufficient to prevent effectually the loss of any gas.

Fig. 587.



The sulphurous acid is admitted into this column through the wide tube at *a*, while immediately above this a jet of steam is thrown in; these together, after traversing the spaces between the shelves and acting on the downward stream, finally escape laden with nitrous gas into the chamber through the passage, *b*.

The jet of steam just mentioned is for the purpose of diluting the nitrous sulphuric acid, and so causing it to yield up more readily the nitrous gas.

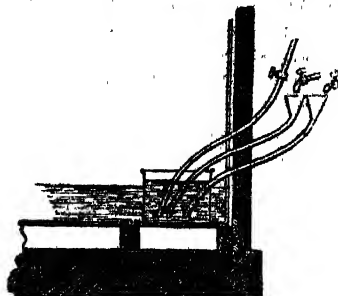
The acid, by the time it reaches the bottom, is supposed to be thoroughly denitrated, and is conducted thence to an evaporating pan to be concentrated, in order that it may be once more used for the absorption of a fresh portion of gas in the absorbing column. Theoretically considered, the nitrous vitriol ought to run from the lower portion of the apparatus without containing more than a trace of any nitrous body. On the contrary, it might be expected to be charged with sulphurous acid, but practically this does not appear to have been the case; for, from the statement of those who had ample opportunity of examining its action, it appears that the nitrous constituent was never thoroughly eliminated, that it still retained a considerable quantity of this gas after very slowly traversing the apparatus, and that this impossibility of thoroughly decomposing the compound acted as a strong barrier to the introduction of the invention. But, happily, this defect was not unconquerable, and was, by a reasonable amount of skill and patience, eventually obviated, at least practically so, if not perfectly.

The nitrous sulphuric acid is decomposed, but comparatively slowly, when subjected to the action of sulphurous acid in an undiluted state; and this appears to have been the cause of the failure in the commencement, inasmuch as the acid flowed from the decomposer almost of the same density as when introduced. It would seem inconsistent that the expedient of mixing it with water so as to dilute it was not adopted, especially as the decomposing action of water *per se* must have been observed. Doubtless this would have solved the problem, especially as with this addition a modification of his apparatus answers very well.

The mere dilution of this nitrous sulphuric acid with hot water answers very well. This is done within the chamber. A section of the apparatus employed is shown in Fig. 588. It consists in simply placing within

the chamber, and as near the burner stalk as possible, a round leaden vessel about twelve inches high and eighteen inches diameter. This is placed close to the

Fig. 588.



leaden wall of the chamber. This leaden wall is pierced by three tubes, all terminating within the leaden vessel, and near to its bottom. One of these tubes conveys the nitrous sulphuric acid into the vessel; the second conveys water; and the third is a steam-pipe. The two tubes for the liquids terminate on the outside of the chamber in funnels, while above these funnels are the respective taps, one of which communicates with the nitrous vitriol-store cistern, and the other with the supply of water. The steam-pipe is, of course, in connection with a generator.

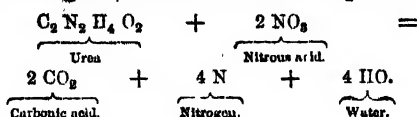
Supposing the chamber to be at work, the mode of operating, with this arrangement, is very simple. The leaden box or vessel is first run full of water—this is by means of the steam jet brought to boiling. The operator or workman then proceeds to run in a slow stream of nitrous vitriol and water from their respective taps. Immediately the nitrous vitriol touches the hot water below, it decomposes into sulphuric acid simply,—which remains in the vessel for a while—and nitrous gas, which flies off, and which is, by the current of gas ascending from the burner, carried off, and enters into the working of the chamber.

Of course, the vessel always remains as near as possible full. The streams of fresh liquid running in immediately displace and drive out a portion of the previous contents, causing it to mix with that already contained in the chamber.

There are at least two advantages which arise from placing this decomposer as near the burner-pipe or gas tubes as possible. In the first place, the gas arising from the decomposition has a better chance of thoroughly mixing with the rest of the gases which form the chamber mixture; and, in the next place, this rapid removal and immediate mixture lessens the risk of local action on the chamber, nitrous gas being rather destructive to lead. In fact, the rapid current of sulphurous acid gas must sweep away every particle of nitrous gas as fast as it is liberated. One of these decomposers has been working in a chamber for nearly three years, and the lead in its immediate neighborhood does not appear to have suffered more than that in any other part of the chamber.

Mr. PETER HART of Manchester has given a method of estimating the value of this nitrous vitriol

by a process of analysis by which one may, in a very simple manner, determine how much nitrate of soda or nitric acid a given volume of this nitrous vitriol represents, or is equal to. The process is founded on the well known reaction which takes place on bringing nitrous acid and urea together, the result of this proceeding being the formation of water, nitrogen, and carbonic acid gases, as shown in the following formulæ—



Mr. HART prefers to employ urea, in the shape of nitrate, on account of the facility with which it can be obtained pure. Of this nitrate of urea he weighs out twenty grains, and dissolves this in about two and a half ounces of water, heating this solution to boiling over a gas lamp. Meanwhile he prepares a test liquid, composed of thin starch water, in which he dissolves a small quantity of iodide of potassium. He spots a white plate with drops of this liquid. He then fills up an ordinary alkalimeter with the nitrous vitriol to be tested. Meanwhile the solution of urea has arrived at boiling, at which point he lowers the gas flame, and proceeds to add the nitrous vitriol from the alkalimeter to the solution in the basin. The reaction goes forward with strong effervescence, and escape of nitrogen and carbonic acid gases. He continues to add the nitrous vitriol drop by drop, not neglecting to stir until a drop, taken out of the basin by means of a glass rod, and added to one of the test spots on the plate, causes the latter to assume a blue color. This indicates the completion of the operation. The number of measures used or added are read off, and this forms the data for the calculation. The rationale of the process is very simple. After the decomposition of all the urea, the nitrous acid, which hitherto has been simultaneously decomposed with the urea, now remains in a free state. Now, it is well known that nitrous acid decomposes hydriodic acid, setting iodine free, which iodine will immediately combine with starch, if any be present. This is one of the tests for nitrous acid; so in this case the formation of the blue coloration indicates free nitrous acid in the basin; and free nitrous acid present indicates the decomposition of all the urea.

The calculation is based on the fact, that to decompose the twenty grains of nitrate of urea employed, there would be required 12.35 grains nitrous acid, NO_2 , which is equivalent to, or represents in chamber effect, 17.56 grains nitric acid, NO_3 , or 27.64 grains nitrate of soda; consequently the number of alkalimeter measures of the nitrous vitriol required in the decomposition represents or contains the equivalent of any of these numbers. All that remains to be done is, to ascertain the relation borne by this quantity to the volume which the cistern is capable of holding, or contains at the time of the experiment; or to put it as Mr. HART gives it—let a represent the number of alkalimeter measures employed of the nitrous vitriol; b the nitrate of soda—if the result is required in nitrate of soda—corresponding to the twenty grains of nitrate of urea, as given above; c the number of alkalimeter measures in a gallon—

seven thousand—and d the number of gallons in the cistern; then—

$$\frac{b \times c}{a} \times d = x$$

x indicating the equivalent in nitrate of soda of the recovered nitrous acid in the entire cistern.

Another method of recovering the nitrous gas has been lately patented in this country. It differs very considerably from the one already described, that is, in principle, although the apparatus bears a great resemblance. It consists essentially in converting the nitrous gases into nitric acid, and combining this acid with lime. The inventor starts out with a column, as in the last process, filled with suitable materials to afford a large surface, down which he runs a stream of thin milk of lime, allowing the waste gases from the chamber to ascend in the opposite direction. In this case it is supposed that, under the influence of the alkaline fluid and excess of atmospheric oxygen, the oxides of nitrogen will be wholly converted into nitric acid, which will immediately combine with the lime, forming nitrate of lime.

It is well known that nitric acid can be reproduced from any of the lower oxides of nitrogen—with the exception of, perhaps, the lowest, nitrous oxide, NO , when in contact with water and free oxygen. This has been dilated upon, and the reaction given when treating of the chamber reaction; and that this is a fact there is no doubt. The only difficulty hitherto appears to have been to obtain nitric acid of a suitable strength. This has scarcely been accomplished, as experiments have shown that the reaction proceeds with less rapidity as the acid gains density. But where lime-water is used this objection is removed, inasmuch as no free acid can exist in the liquid to retard the reaction; each atom of this acid being removed or combined at the moment of its formation, or immediately afterwards. There is no doubt that the presence of an alkali not only obviates this retardation, but actually induces, by its presence, the combination of the lower oxides of nitrogen with oxygen, thus, in fact, acting in a doubly advantageous manner.

The solution of nitrate of lime, formed in the column, is run into a proper cistern placed for its reception and conservation prior to its being converted into a dry or crystalline salt, which the inventor proposes to employ instead of nitrate of soda, as a constituent of the artificial manures now so much in request.

Perhaps the process would have been more perfect had it been more self-containing, and not dependent on outer circumstances for its perfect well-doing; that is, if the vitriol manufacturer, instead of having to depend on the purchase of this nitrate by other parties, could have used it himself. Were it cheaply decomposable, that is to say, were it possible to eliminate the nitric acid cheaply, it would be better; but it can only be decomposed with ease by the addition of some stronger acid, and the only one reasonably available for this purpose is sulphuric acid. By substituting this nitrate of lime for the nitrate of soda or potassa, ordinarily employed, one would certainly most effectually get back the nitric acid; but, unfortunately, sulphate of lime, a body of no value, would be pro-

duced, instead of, as now, producing sulphate of soda or potassa, salts in great and constant demand.

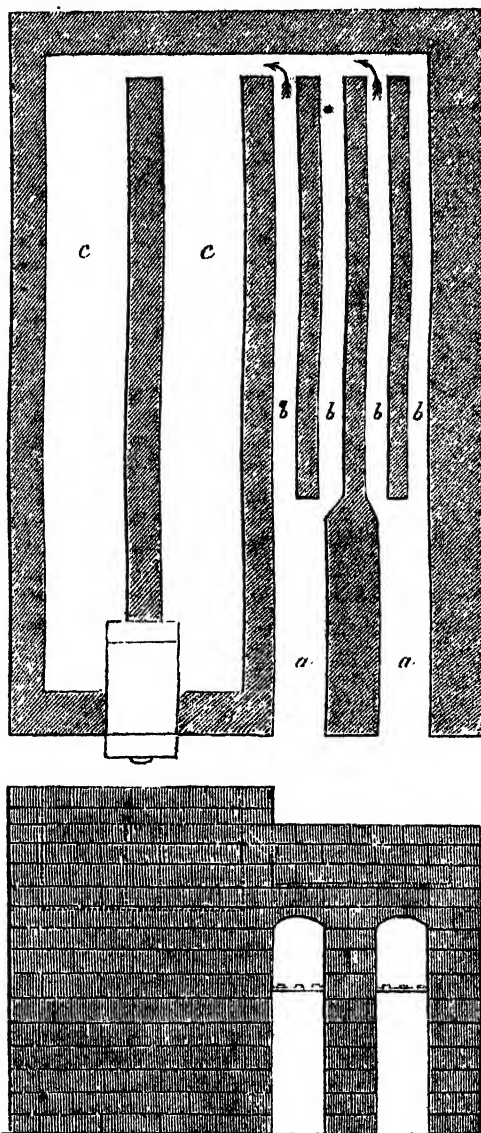
Of the value of processes for the recovery of the nitrous gas little need be said. The benefits they confer are apparent at once, recovering, as they do, the most expensive element in the manufacture, and not only being a saving of the money value of the nitre or its equivalent recovered, but further, when looked at in a politico-economical point of view, another phase presents itself: for were all sulphuric acid manufacturers able to work with half the nitrate they at present use, it would surely tend to reduce the price of this salt; and, if the maxim be correct, that price is regulated by supply and demand, then under the imaginary state of things just mentioned, one-half the quantity now used being thrown on the market, or what is the same thing, not used, must bring down the price of what could be sold, thus lowering a second time the cost of manufacturing sulphuric acid.

Concentration of Sulphuric Acid.—Sulphuric acid, as it exists in the chambers, though strong enough for many purposes, is not sufficiently so for sale, inasmuch as it is the object of the manufacturer to send it out as strong as conveniently may be, in order to avoid the necessity of conveying a quantity of useless water. It is concentrated up to a certain point in leaden pans; that is, until it has attained the density of 1.750; beyond this point it is not considered safe to push the concentration in lead. In order to bring it up to its maximum degree of concentration, or its conversion into what is termed rectified oil of vitriol, the extrication of the further remaining quantity of water must be performed in vessels of glass or platinum.

With respect to its concentration in lead a variety of plans are in use for this purpose. Much difference of opinion exists on this head amongst sulphuric acid manufacturers; their choice probably depending on convenience and situation. One manufacturer, for instance, prefers to concentrate his vitriol by passing the flame and products of combustion of a fire over the surface of his weak acid, the watery vapor being carried away with the smoke, *et cetera*. This plan appears to answer very well where no niceness with respect to the color and purity of the acid is demanded—as when the vitriol manufacturer is also a soda manufacturer, and uses up his own acid; but as the concentrated acid resulting from this mode of working is almost invariably very black and turbid in consequence of particles of coal-dust, *et cetera*, falling into the hot liquid, as well as from contact with the various carbonaceous bodies forming coal smoke, such acid would be scarcely saleable in the ordinary way to calico-printers, bleachers, and other such consumers. In order to avoid this, the manufacturer must employ an apparatus in which the liquid is kept clear from all or any such contaminations. For this purpose a pan in principle, though not in shape, resembling an ordinary pan or boiler, must be employed. This variety of concentrating boiler is in very general use, being, in fact, almost universal amongst those manufacturers who sell their acid; whilst the surface concentrator is as commonly employed amongst the soda manufacturers and others, who make the acid solely for their own use.

The following describes the plan of a manufacturer who makes for sale only. This plan is found to answer very well; it consists of two pans, placed side by side, one being placed higher than the other—so high that its contents can be emptied completely by means of a siphon into the lower pan. No joinings or solderings of any kind are admissible about these pans, the whole must be formed out of one solid sheet of lead,

Fig. 589.



the sides and ends being turned up simply: the lead is half an inch thick, the other dimensions of the sheet being thirty-three feet by seven feet six inches. To form such a pan, the sheet of lead is first spread out on the bed prepared to receive it; the plumber proceeds to mark off eighteen inches from each side of the sheet; this is to form the sides and ends of the pan. To faci-

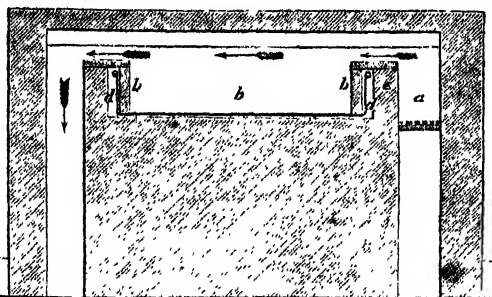
litate the bending, a fire of shavings is made along the line of markings. When the lead has become sufficiently hot along these lines, he proceeds to bend up the sides, and to beat out any inequalities. The brickwork setting of the pans will be understood from the preceding figures, in which Fig. 589 represents the arrangement of the flues, previous to being covered in with the fire-tiles or iron plates on which the bottom of the pan is to be placed; the left hand portion represents the bed of the lower pan, while to the right we have that of the upper one. *a a* are the two fireplaces, the flame from which proceeds along the narrow flues or passages, *b b b b*; they turn off at the end in the direction of the arrows, and return beneath the upper pan; along the two wide flues, *c c*, and from thence pass into the wide flue leading to the chimney. Fig. 589 is a vertical section, lengthways, of the fireplace of the lower pan; *c* is the course of thick fire-tiles immediately over the fire, protecting the pan from the too great heat; a little beyond the fire thinner tiles are employed, which thin tiles are continued to the end. The two wide passages, *cc*—Fig. 589—beneath the upper pan are covered with iron plates, half an inch thick, on which the pan is placed. It will be understood from this description, that the tiles, or other supporting medium, diminishes in thickness, but increases in conducting power as the distance from the fire increases. This arrangement is necessary, for were iron plates used the whole distance, they would soon be burned through and destroyed in the immediate neighborhood of the fire; and, on the contrary, were thick tiles used for the whole distance, the latter portion of the arrangement near the end of the pan would offer too much resistance to the passage of the heat, and consequently a considerable portion would pass away without being absorbed.

Two such pans are capable of concentrating the acid produced from eight tons of sulphur per week of six days. There are pans at present in use capable of concentrating forty tons of vitriol weekly. Their mode of working is as follows:—The vitriol in the lower pan being of the proper strength, the workman proceeds to run it off into a vessel called a cooler, where it remains until cold. He runs it empty to within two or three inches; when this is accomplished, he proceeds to set a siphon into the upper pan, running the contents into the lower one, which lower one he fills within two or three inches of the top. When the upper pan is empty he refills it with the weak acid from the chamber; he then proceeds to fire the pan until next day, when he will repeat the operations just described.

The other description of pan, the one spoken of as a surface concentrator, is of the following description: Fig. 590 being a vertical section lengthways, the fireplace is at *a*, the flame, *et cetera*, proceeding in the direction of the arrows over the surface of the dilute acid at *b*, when it descends into the flue, carrying with it the evaporated water. It resembles—with the exception of some particular details, to suit the material to be evaporated—the furnace described under the head ALUM in this work, Fig. 89; but in the case of sulphuric acid, the furnace has to be lined, so to speak, with lead; and this lead being liable to fuse at a comparatively low temperature, much ingenuity is

displayed in the methods adopted to prevent as much as possible such an occurrence. One mode of accomplishing this is shown in Fig. 590, where *d d* is a section of the leaden pan, inclosed in brickwork, to prevent

Fig. 590.



the action of the flame. The side of the pan is brought up to the furnace dam, *e*; then within the pan a close row of firebricks, *b*, are placed on end, but not cemented in any way. Thus the sides of the pan are inclosed between brick walls, it only remains to cover up the space, and this is done by placing firebricks on the top, resting partly on the furnace dam, and partly on the row of bricks just mentioned; the flame is thus completely kept off the lead. This is repeated all round, the pan's sides and ends being equally protected. Some manufacturers employ a slightly different arrangement, although on the same principle. A covering brick, expressly made for the purpose, is employed; these bricks are made of the proper size, with an indentation or channel formed in them; this channel being for the purpose of inclosing the upper edge of the pan, side or end. This arrangement is shown in Fig. 591, where *a* is the pan edge; *b*, the brick or tile, with its channel, *c*, inclosing the edge of the pan.

Fig. 591.



Though these precautions would appear to be sufficient, yet the manufacturer usually avails himself of another invention, which consists in running a stream of cold water round the pan's edge. This is effected by burning or fusing—by means of the hydrogen apparatus mentioned in another portion of this article—to the edge of the pan a leaden tube of a D shape, the flat side being next to the pan; a section of this pipe is shown in Figs. 590 and 591. This arrangement has a current of cold water constantly flowing through it.

These vitriol pans are often of immense thickness, in some cases the lead of which they are made is an inch thick; but as the heat does not, as in the previously described pans, penetrate through this, it is immaterial. They are worked rather differently to the other pans, inasmuch as it is necessary to cool them to a much lower temperature before running them off. Before this is done the fire must be slackened, or rather put out; for, were the pan to be emptied while the fire was burning with its usual vigor, the pan sides might get so hot as to become soft, and fall or bend down. The upper portion is an arch of firebrick, through which a hole is pierced over one corner of the pan;

through this hole the siphon is inserted for drawing off the finished vitriol; it is also refilled with dilute acid through this. The workman ascertains the progress of the concentration, or its completion, in all cases by taking out a portion from time to time, and placing the vessel containing this trial sample in water to cool. When cold enough, he ascertains the density by means of the hydrometer. When finished it must, as before stated, be of the density of 1.750, or of the strength of 150° on TWADDELL'S hydrometer—the instrument most used in this country—when at a temperature of 60°. When of this density, he draws out the fire and proceeds to run the vitriol into what are called coolers, which, as their name indicates, are for the purpose of holding the acid until sufficiently cool to run off into the glass bottles called carboys, for sale or transport to its destination.

These coolers, which are simply shallow lead vessels almost identical with the first-described pans, are, like the latter, formed out of an entire sheet of lead, sometimes half-inch, often of quarter-inch thick. This is, of course, an indifferent matter. The half-inch will last much longer, nevertheless it is not advisable to make them of less than quarter-inch. These coolers are set on iron plates in the manner described with reference to the upper pan; but the ends of the flues are open to the air, which, circulating through these passages, carries off the heat. The sides and ends are held up by brick walls or other convenient supports.

Very good and efficient coolers are constructed as follows:—The dimensions of an iron vessel, capable of holding the quantity of vitriol likely to be run off from the pan, are calculated—these parts are cast of about half-inch thick iron in such a manner that the whole can be securely bolted together. No care is requisite with respect to the accurate fitting of the various joints, as the whole must be lined with say quarter-inch lead. This lead must be turned over the upper edge and flattened down so as to prevent any infiltration of acid between the iron and the lead. If this is not attended to, the acid which finds its way down will act upon the iron, producing protosulphate of iron in masses. These will continue to grow in size, and in so doing will push the lead from the iron, producing misshapen prominences, which will finally destroy the cooler, or rather necessitate the removal of the lead lining, the cleaning the surface of the iron, and finally relining with lead. Two of these coolers, of six feet square and two feet deep, have been in use for some time; they cool the vitriol very rapidly. They are not set on the floor, but on two low walls of brick, so that almost the whole surface of the iron is exposed to the cooling influence of the atmosphere, and the heat is quickly carried off.

It is possible to construct coolers by simply lining a wooden cistern with lead: such are used for crystallizing various salts; but it is a question whether they can be recommended, inasmuch as the cooling must be very slow, on account of the bad conducting quality of the wood which forms the coating to the lead.

In most vitriol works two coolers are used in connection with the pan or pans. Suppose they are called No. 1 and No. 2, the mode of working resem-

bles that of the pans first described; that is, No. 1 is supposed to be cool enough to bear bottling. When this is done, the contents of the upper cooler, or No. 2, is now run into No. 1, while No. 2 is now ready to receive a fresh quantity from the lower concentrating pan. It will thus be seen that in working a set of concentrating pans and their accompaniments, four stages may be recognized. The upper pan partially concentrates the acid ready for the lower pan, which then completes the concentration. From this lower pan it is run into the upper cooler, where it loses the greater portion of its heat, and finally it is run into the lower cooler, where it remains until quite cold or nearly so.

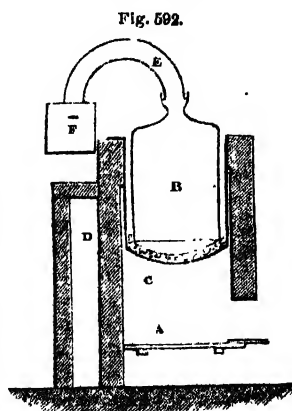
The system just described is in constant use in some works, but is not by any means universal, each manufacturer limiting the extent of his apparatus to his wants. The arrangement most usually seen, especially in small works, is a single boiling-down pan, as it is technically termed; the heat passing beneath it up one flue and returning to the same end down another, after which it passes to the chimney. This pan is accompanied by one cooler. The raw acid from the chamber is run into this single pan, where it is concentrated up to the proper point, after which it is run into the cooler, where it stays until cold; and if the pan is ready to run off again before the vitriol in the cooler is cold enough, there is no help for it, but drawing the fires and letting it stay in the pan until it can be accommodated.

There is no objection to this system except, perhaps, that it is not calculated to do much work; still it answers sufficiently well for small manufacturers.

The manufacture of sulphuric acid has now been traced to the completion of a commercial product, which, in the language of the trade, is called brown oil of vitriol, in order to distinguish it from a product of still higher concentration, to be immediately described. This brown oil of vitriol is used to a large extent by bleachers, calico-printers, dyers, and others; its brown color, from which it derives its name, is due to a certain amount of organic matter which finds its way into it, and which, subjected to the joint action of the acid and heat, becomes carbonized, and colors the whole of a dingy-brown hue. This tint is often augmented from accidental circumstances. Sometimes the workman lets the rag or paper protector, with which he covers his hand while setting the siphon, drop into the pan, at other times fragments of wood-shavings or sawdust find their way into it; when this is the case the vitriol well deserves its name of brown; perhaps, under these circumstances, black would more nearly designate its color. When such an accident occurs, it is usual to destroy this black or brown color by sprinkling a small quantity of some highly oxidizing body into the vitriol while hot in the pan; either nitrate of potassa or soda answers well for this purpose. Finely powdered black oxide of manganese may be used. These bodies yield up sufficient oxygen to the black matter to destroy it, or convert it into some colorless body which does not offend the eye.

Monohydrated Sulphuric Acid—Rectified Oil of Vitriol—English Oil of Vitriol.—Brown oil of vitriol is not sufficiently strong for several purposes; amongst others may be enumerated the manufacture of the dyeing

compound known in commerce as extract of indigo, sometimes called sulphate of indigo. Fuming Nordhansen acid is often directed to be employed in the formation of this body, but in this country it is usual to employ the strongest English sulphuric acid. In order to procure this acid the following methods are adopted:—It has been stated previously that the concentration cannot be safely conducted in lead beyond the density of 1.750, for if driven further, not only would the metal be rather strongly acted upon, but there would be considerable risk of the pan-sides falling in, in consequence of the softening of the lead; so high would the degree of heat become before the last portion of water could be driven off. The further concentration, then, must be performed in vessels made of a material which will withstand the corrosive action of the boiling acid, and which is comparatively infusible. Glass at once suggests itself or some variety of earthenware, such as porcelain, or, amongst the metals, platinum or gold. Of the former two glass offers most advantages, and of the two latter materials platinum is preferable, inasmuch as it resists acids quite as well, and is much cheaper than gold. Glass has been employed in the concentration of vitriol from very early times, perhaps from the period when sulphuric acid began to be understood, and its manufacture attempted on a very small scale, doubtless before the introduction of leaden pans. Platinum, on the other hand, is a comparatively late introduction. The glass vessels employed in the last concentration of sulphuric acid, or, as they are technically known, retorts, resemble very much the bottles or carboys used to transport vitriol from place to place. Their figure is shown in section in Fig. 592, which represents the whole arrangement when at work.



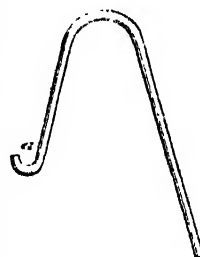
These retorts vary some little in size, manufacturers having lately begun to use much larger ones than were formerly employed. Those in use at the present day are capable of holding more than twenty gallons of liquid, inasmuch as after the rectification or concentration there remains in the retort sufficient vitriol to fill two carboys. This is equal to twenty gallons.

The mode of working can be gathered from the drawing, where A represents the fireplace; the flame, *et cetera*, from the fire plays round the cast-iron pot, C, finally making its exit into the flue, D. On the bottom of the

iron pot just mentioned a quantity of dry sand is laid; and on this the retort, B, is placed, the sand serving as a steady support for it. The retort is not, as is sometimes supposed, surrounded with sand; for, if this were done, it would run some risk of being broken, besides materially retarding the cooling when the rectification was over.

The retort being placed, as in the drawing, it is filled with cold brown vitriol; and when this is done the fire is lighted; the arm, E, is put into its place; the apparatus gradually warms up, and eventually the acid boils; water, with a little sulphuric acid, distils off. This vapor passes off by the stoneware arm, E, into the leaden draught-pipe, F, where a quantity of it condenses; but the greater portion finds its way from thence into the chimney. The contents of the retort are kept boiling for some hours, or until the brown color entirely disappears; for this appears to be the only reaction by which to determine the conclusion of the rectification. It would appear that the organic matter resists the destroying or oxidizing action of the acid, until it has reached its highest point of concentration and temperature. When the clearing has taken place, the fire is withdrawn from beneath the pot; and the whole arrangement is allowed to cool down to a safe temperature, when it is drawn off into carboys. This drawing off is effected by a peculiar siphon, being in fact what is known as MITSCHERLICH'S siphon; but in this case, on a rather large scale, as shown in Fig. 593, it consists of a siphon, with the shorter of its two legs turned back upon itself, as shown at a. This turned-up portion should be as short and

Fig. 593.



as close to the siphon leg as possible, in order to be the more easily inserted into the neck of the retort; it is rather exaggerated in the drawing. In order to withdraw the concentrated acid from the retort, the workman first removes the earthenware arm; the siphon is filled with water, the man keeping his thumb firmly closed over the orifice of the longer leg. The shorter leg is inserted into the retort, and gently placed on the bottom; the workman then removes his thumb for a few seconds, until the acid has driven before it the water with which the siphon was charged; when this is done, the end is directed into a carboy which has been placed in readiness by an assistant. When the carboy is full the orifice is again closed by the thumb, while the full carboy is removed and replaced by another empty one. The whole range of retorts are emptied in this manner.

This product is the strongest English sulphuric acid; it is colorless or nearly so, and is of the density 1.850, or 170° on TWADDELL'S hydrometer.

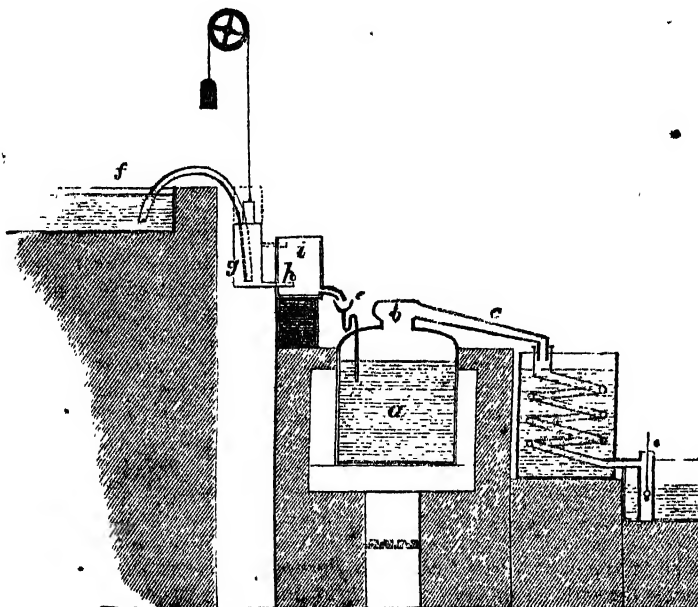
When treating of the commencement of this process, the retort was directed to be filled with cold brown oil of vitriol; it was supposed in this case that the retort was newly starting; but as one charge is now supposed to have been worked off, it will be more or less warm, and the introduction of cold vitriol at this junct-

ture might possibly fracture it. Therefore, it will be necessary to recharge it with warm vitriol, or with vitriol as nearly the same temperature as the retort as possible; and this must be made a rule, if annoyance would be avoided.

It is usual to find in books treating of this matter, the apparatus for rectifying in glass described as con-

sisting of a great number of the retorts, with their accompanying sandpots, *et cetera*, set in a battery, that is, a number of them heated by one fire. Though this may have been the case at one time, it is not the practice or custom to operate in this manner at the present day. Such an arrangement could not have worked as well as the present one, the probabilities being that the

Fig. 594.



retorts which were placed nearest the source of heat, would arrive at their maximum point of concentration some time before those at the end of the arrangement furthest from the fire were finished; in such a case it would have been necessary to have kept on firing until the whole set were done. The result would be that a considerable quantity of sulphuric acid would have distilled off the finished retorts, while those in the rear were being finished. In the present arrangement each retort is by itself, has its own fire, and consequently works totally independent of its neighbors.

The defect of this system of operating is the great fragility of the operating vessel, and the consequent liability to fracture either from a blow or other accident of the kind, or from change of temperature. The room or shed in which a concentrating plant of this description is working, should be closed, and every precaution taken to prevent the access of draughts of cold air or other cooling influence. It is no uncommon occurrence for two or three retorts to be cracked round the top, from the sudden rush of cold wind through an opened door, in such a manner that the whole upper part of the retort could be lifted off; the crack having gone completely round it, and severed the upper portion as completely and as straight along the protecting edge of the sandpot, as though it had been done with a diamond. Mr. JONES of Bristol took out a patent in the year 1845, for a protector to obviate this

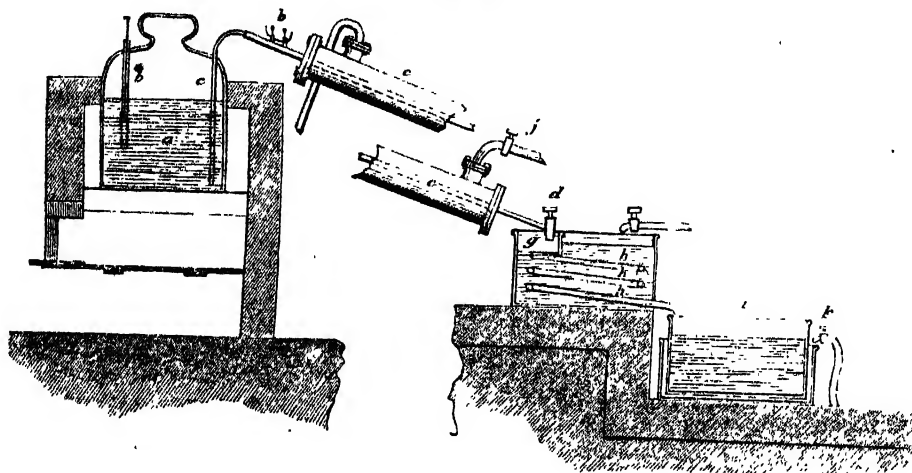
accident. The protector consisted of a sort of sheet-iron bell-jar, if such a term may be used; this bell-jar has a hole cut in the upper portion, so that the whole may be placed over a retort when in work, the neck of the retort protruding through this orifice, while the lower edge of this cover rested on the upper edge of the sand-pot. Such an arrangement effectually protects this part of the retorts from cold draughts, or drops of cold liquid, which, as may be easily imagined, are equally destructive. In fact, any cool or cold body coming in contact with the heated glass is fatal to it, causing much inconvenience; for not only is the retort itself destroyed, but the contents are lost, also creating the greatest annoyance and discomfort, for the vitriol trickles or runs out, and, coming in contact with the red-hot pot, is converted into vapor of a most suffocating kind, filling the whole place. This calamity is without remedy; and even though a remedy were to present itself, it would be impossible to enter the place, and apply it, without running considerable risk of suffocation.

These risks and drawbacks were doubtless the stimulants which brought out the platinum retort, this costly, but efficient substitute being safe from the casualties just described. This retort, with its appendages, is shown in Figs. 594 and 595. The former is a vertical section in front; *a*, is the body of the retort; *b*, the head; *c*, a platinum tube leading from the head to a

leadern worm, which worm is kept immersed in water; *e* is a platinum funnel, the tube of which is S-shaped, to prevent the return of any vapor. The brown acid which is kept in the cistern, *f*, under which the waste heat passes, is run into the body of the retort without the aid of any tap or valve by means of the at-first sight rather complicated, but really simple apparatus shown in the figure, where *g* represents a round vessel in which a tube, *h*, is inserted very near to the bottom; *i* is another leaden vessel, which has a slit in the side

from the top nearly to the bottom, along which slit the tube, *h*, slides, when the vessel, *g*, is moved up or down by means of the chain and pulley. A siphon, which is kept constantly set, connects the stock cistern, *f*, with the vessel, *g*. The apparatus, when in the inactive state, as represented by the dotted lines, is as follows:—The siphon is full of vitriol, but the surface of the acid in the cistern being on a level with that in vessel *g*, no flow can take place; when the vessel, *g*, is lowered, the levels become altered; and as the leg of

Fig. 595.



the siphon, which is in vessel *g*, becomes the longer, the acid begins to run into this vessel, and from this into vessel *i*, and thence into the funnel.

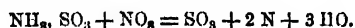
The other portions of the apparatus being at the back, are shown in Fig. 594, which is a side view; *a*, as before, is the body of the retort; *b*, is a platinum tube about three-fourths of an inch in diameter, in which a glass float is placed to indicate the depth of liquid in the still; *c*, is a siphon, also of platinum, of the same diameter as the tube just mentioned. This siphon is inclosed in an iron tube, *d*; between these two tubes a current of water can be passed. The siphon terminates in a platinum tap at *d*. The body of the still rests on a circular tile of refractory clay; the fire being below this tile, the flame rises at the back of the still, circulates round the sides, and finally passes from thence under the stock-pan. The course is shown in Fig. 595.

The mode of working this still is as follows:—The workman fills up his still a few inches above the highest point the flame is likely to reach; the fire is lighted and kept on until the contents are brought to boiling. The concentration then commences; vapor passes off through the head and conducting tube into the worm, where it again resumes the liquid form, running out into a vessel placed to receive it. This liquid is always acid, but at first it is very weak; it eventually reaches a density of 1.2400. When this strength is attained, the workman knows that the highest degree of concentration is arrived at. If the running-off siphon, *c*, is not set, he proceeds to do this by closing the tap, *d*. The two plugs are removed in the funnel, *f*, and the siphon is filled with vitriol; the plugs are replaced. It

now only remains to open the tap, when the contents of the still begins to run off. The tap is allowed to remain open, until from three to four inches of the still contents are drawn. The workman is guided in this by the indications of the glass float before spoken of, which serves as a gauge. The acid falls into the cup, *g*, thence it flows through the serpentine coil of pipe, *h, h, h*, which is immersed in water; and finally it emerges still slightly warm at the end of the coil, and runs into the receiving vessel, *i*, which vessel stands within another one, a stream of cold water from the tap, *k*, circulating between the two. The water tap, *j*, is also turned, when running off, so that a stream of cold water cools the siphon itself. When the operation is over, the workman proceeds to repeat the course of operations just described; he fills up his still to its former level, attends to his fire, heats it up to the proper point, and again allows the acid to run off.

Such an apparatus, the still itself having a capacity of from seventy to eighty gallons, is capable of producing thirty carboys of rectified oil of vitriol in twelve hours, two carboys being all that a glass retort could produce in twenty hours; but this of course is owing to the latter requiring such a length of time to elapse before its contents can be safely drawn off. A retort of the above dimensions, with the siphon and float case, costs about fifteen hundred pounds, the price varying according to the thickness of metal, and consequently weight of platinum, yet it is generally admitted to be a more economical plan of operating than the glass retort system. But it is not free from disadvantages; it is necessary to be careful that the vitriol contains no nitrous

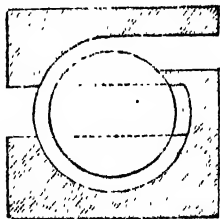
compound, for if this be the case, the platinum is rapidly attacked. To obviate this, it is usual to add a quantity of sulphate of ammonia to the acid, while in the leaden concentrating pan, before it enters the still; the action of this salt is to decompose the nitrous body usually existing in vitriol. It is supposed that the following is the decomposition which takes place, assuming nitrous acid to be the body present:—



This may occur in some cases, but it is not the invariable result. If a *little* sulphate of ammonia be dissolved in a small quantity of the nitrous vitriol of GAY-LUSSAC's column, and the whole heated in a test tube, either NO_2 or NO is evolved; nitrogen very probably is given off at the same time, but it is not the only body eliminated. When a rather large excess of sulphate of ammonia is employed, sulphide of hydrogen is formed in the still, and can be detected by the smell at the end of the condensing worm; undoubted evidence of its presence has been detected by means of lead paper. The only rule that can be laid down for guidance as to the quantity to be used, is the addition of an increased quantity of the salt each day until nitrous bodies cannot be detected in the finished vitriol; the workman at last obtains a good idea of the quantity to be added.

Sulphuric acid is brought to a saleable condition by the employment of one or other of the methods just described; but although these methods are universally employed, others have been proposed. The patentee who proposed to generate the steam necessary for the chamber by the combustion of the sulphur, also pro-

Fig. 596.



posed to concentrate vitriol or any other liquid by means of the heat from this source, hitherto, in the inventor's opinion, wasted. The idea is very ingenious, perhaps more so than practical; but it would appear to be doubtful whether it is possible to concentrate vitriol at all by this process. The probability is that the sulphur would begin to sublime before the vitriol could be brought to the proper strength. The process is not in use in any part of the country, so that one may naturally infer that it is without practical value.

Perhaps the most ingenious proposal for the concentration of vitriol is the one about to be described, the prevailing principle of which is that of carrying over its surface streams of hot air, which, liberating and combining with the water, carries it off. The apparatus consists of two distinct portions, the one devoted to the production of highly heated air, and the other to the concentration. The former portion of the apparatus consists of a series of iron pipes, *a*—Fig. 597—set in brickwork; these tubes are heated externally by the flame of the furnace, *b*, the products of combustion from which pass up the space, *c*; they then descend and circulate round the tubes, finally making their exit into the main flue by means of the openings, *d*. The cold air

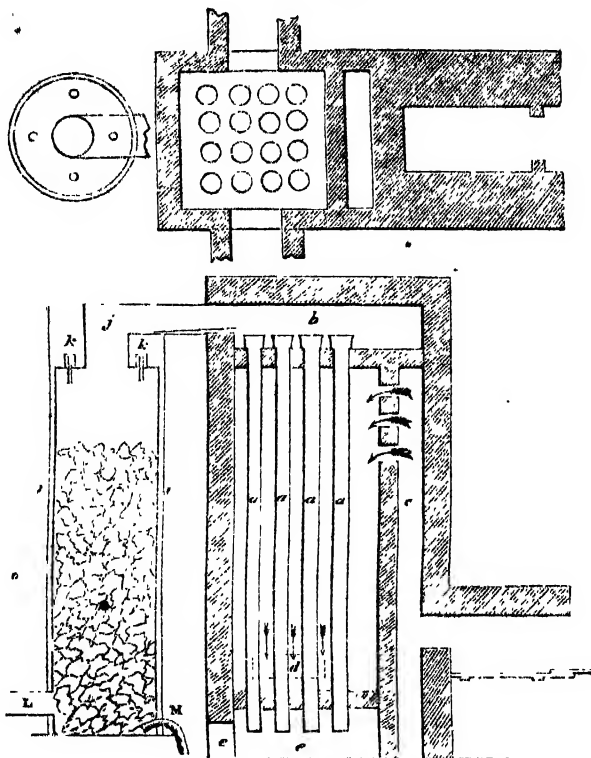
from without enters the lower ends of the tubes which project into the arched recess, *e*, passes up them, and, becoming highly heated during its progress, enters the space, *f*, and passes along the wide iron tube, *g*, and thence into the concentrator. The portion of the apparatus devoted to the concentration is constructed entirely of lead; it consists of two concentric cylinders, *h, h*, made of half-inch lead; *i, i*, is a small space, the use of which will be explained hereafter, which exists between them; both cylinders are closed at the bottom by being fused on to one sheet of lead; the inner cylinder is partially closed at the top, space only being left for joining on the leaden tube, *j*, which is a continuation of the iron tube, *g*, spoken of before, and is for the conveyance of the heated air. The inner column or cylinder is filled with coke, or other suitable material, which offers a large surface for the acid to spread itself over, at the same time being unattacked by it. The following is the method of working this apparatus:—The opening into the arched recess from which the cold air is drawn must be closed, or if there be a damper or register beyond the concentrator between it and the chimney, this must be pushed in. The furnace must be heated up until the pipes and the chamber containing them are of a good red heat. This state of preparation having been arrived at, the vitriol to be concentrated must be run on to the top of the inner cylinder; it runs down and fills up the space existing between the two cylinders, rising up to the mouths of and running down the tubes, *k, k*; these tubes are covered with lead caps, the bottom edge of these being immersed in the vitriol from an air-tight joint, which prevents any cold air being drawn in. The vitriol on flowing through these tubes spreads itself over the whole surface of the coke, wetting it thoroughly. When sufficient vitriol has been run in to saturate the whole of the coke, the hot-air current is allowed to enter it, penetrates every space and crevice in the mass, and heating the vitriol up to a high point, carries off its water finally when saturated, making its exit into the chimney by means of the wide tube or pipe, *l*. The vitriol becomes more and more concentrated, the nearer it approaches the lower part of the cylinder. When it has arrived at this point, if the amount of acid and hot air have been proportioned to each other, it will be found to be fully concentrated. It collects in a stratum at the bottom, until the surface rises sufficiently high to flow off into a proper reservoir or cistern through a bent tube, *m*. The use of the double cylinder has two advantages—it heats the sulphuric acid somewhat, previous to its admission into what may be called the concentrator proper; and also keeps the latter cool, or rather lessens the risk of its fusing if too great a heat should be employed.

The apparatus in the form just described, though capable of concentrating vitriol, cannot be said to be a success. The fusion of the lead in the upper portion was the weak point in this invention; in order to work the apparatus with practical efficiency, it was necessary to have the air highly heated, in fact the current of air may be said to have been red hot. Under these circumstances it was almost impossible to avoid the fusion of the lead tube which conveyed the hot air from

the heater. This great difficulty, combined with some minor ones which, however, might be obviated, caused the inventor to relinquish the idea. Although not an

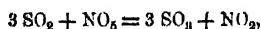
invention or process capable of being carried on in its present shape, yet, in the hands of a patient operator, it might be made to yield better results. It would

Fig. 597.



probably be a work of no little trouble and expense, yet if the anticipated result could be obtained, it would amply repay any trouble or expense that might be expended upon it.

Proposed Improvements in Manufacturing Sulphuric Acid.—The efforts of inventors in connection with sulphuric acid, would appear to have been directed to the substitution of some apparatus of smaller bulk, and less costly in construction, than the leaden chambers ordinarily employed. Perhaps the simplest process embodying the above idea is that of Messrs. M'DOUGALL and RAWSON, who included it in a patent obtained by them in 1848. It consists essentially in passing a stream of sulphurous acid gas through nitric acid by which sulphuric acid and binoxide of nitrogen— NO_2 —are obtained as follows:—



but the great point of the process is the continual conversion and reconversion of this NO_2 into nitric acid, to be again used as before. The inventors say, that the reaction which ensues may be best described by symbols. Thus when 3NO_2 —the NO_2 evolved in the first reaction becoming NO_4 by combining with the excess of oxygen, which as atmospheric air accompanies the sulphurous acid—is passed into water at a temperature of 100° , or upwards, $2 \text{NO}_3 + \text{NO}_2$ results. This NO_3 —or, two atoms of nitric acid—remains in solu-

tion, while the NO_2 , which is an incondensable gas, bubbles through the liquid, and, mixing with the air which is above the liquid, instantly takes two atoms of oxygen from it, and becomes NO_4 ; which, passing again through the liquid, becomes nitric acid and nitrous gas as before: and thus nearly the whole of the nitrous fumes or gas is reconverted into nitric acid. It should be observed that the use of this reaction is claimed in connection with several processes, such as the manufacture of oxalic acid, *et cetera*; but with regard to sulphuric acid, they further say—In our improved method of manufacturing sulphuric acid, we use a series of vessels, similar to that described in the first part of our invention—a modification of Woulfe's bottles, in fact—only that the first vessel of the series is connected with a sulphur burner. The mode of working is to fill the first vessel two-thirds full of nitric acid, and all the others one-third full of water, to charge the burner with sulphur, and then to put in motion the pneumatic apparatus connected with the last vessel of the series. Air is thus drawn over the ignited sulphur, so that sulphurous acid and air pass into a solution of nitric acid in the first vessel, when a portion of the sulphurous acid is converted with sulphuric acid, at the expense of the nitric acid; while the uncondensed sulphurous acid passes into the air, and nitrous gas into the next vessel; and so, as in the first part of the invention, we pass it alternately into water and air, till

the processes of oxidation and condensation are complete. When the working has been continued for some time, we find that the nitric acid has entirely passed from the first vessel, and we have in its place sulphuric acid nearly pure. The same would take place with each of the other vessels of the series, if the nitric acid which has been condensed in the vessels lower in the series, was not again returned to the higher ones, so that when we find the first vessel exhausted of its nitric acid, we remove the sulphuric acid which it contains, and supply it again with nitric acid, obtained from vessels lower in the series. We thus produce sulphuric acid without the loss of nitric acid; as the lower oxides of nitrogen, given off in the oxidation of sulphurous acid, are again converted into the higher oxides, and again used for the conversion of sulphurous acid into sulphuric.

The principle embodied in this process, namely, the perfect recovery of the nitric acid, has been the prevailing idea of many inventors. Some of the other processes to be described are based on the same reaction. About the same time as the date of the above patent, an ingenious modification of their process was being experimented on, of which the following description is an outline:—The apparatus consisted of a burner for the production of sulphurous acid, and an ingenious substitute for the Woulfe's bottles of the last-described process. The burner, *a*—Fig. 598—consisted of an iron chamber, closed up tight, with the exception of an inlet pipe for the admission of air for combustion, and an exit pipe for the sulphurous acid, proper means being allowed for the introduction of the sulphur. The condensing or the conversion part of the apparatus consisted of two leaden troughs or cisterns; but, as they were exact counterparts of each other, a description of one will suffice. This trough, shown in section in the figure, has, what may not be inappropriately called a false top, *b*, a few inches below the real top, *c*. This false top, which was to all intents a sort of shelf, had borders or edges soldered on to it in such a manner that had it been taken out and laid down with its under side upwards, it would have resembled a large, shallow, square dish. This shelf, as just stated, was fastened inside the cistern, within a few inches of the top, and in an inclined

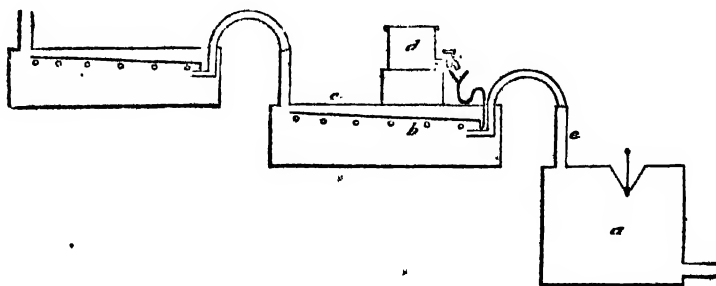
To work this apparatus the two cisterns were first filled with water or weak vitriol, and the vessel, *d*, was filled with nitric acid; a quantity of sulphur was introduced into the burner, and a coal fire ignited beneath it; a stream of air was then turned on through the tube shown in front of the burner, this stream of air being supplied by a pair of bellows, or other suitable apparatus; when the burner attained a sufficiently high temperature, the sulphur ignited; sulphurous acid became generated; this proceeded along the pipe, *e*, and was discharged beneath the shelf, *b*. At this point it was met by a small stream of nitric acid, which trickled from the vessel, the gases rolled beneath the shelf, and from thence beneath the shelf of the second vessel. The reactions, it is scarcely necessary to observe, must have been precisely the same as those in the last-described process; the gases in this case being kept continually in contact with both air and water, and not alternately, as in the former case.

If, in the instances last given, the recovery and *ad infinitum* use of the nitrous gas has been the object, other methods have been invented or discovered by which the use of this body is proposed to be dispensed with altogether. In this latter class of projects, the oxidation of the sulphurous acid has been sought to be effected by the use of some catalytic agent, no cheap chemical body of an oxidizing character having presented itself capable of successfully rivalling the nitrates. The use of spongy platinum, in consequence of its possessing the requisite property in a high degree, naturally was the first suggestion. PARNELL says this was attempted by Mr. PÉREGRINE PHILLIPS. His process consisted in simply mixing the sulphurous acid with excess of oxygen in the shape of atmospheric air, and passing this mixture over balls of spongy platinum at a red heat. The combination took place, and the vapor was received and brought to a liquid state by means of a condenser, like those already described, consisting of a column filled with pebbles, kept constantly wet by a stream of water.

Eventually it was discovered that platinum was not the only body adapted to the purpose; other porous materials, it was found, were capable of effecting the desired union of oxygen and sulphurous acid; for SCHNEIDER states that he has succeeded in converting sulphurous acid directly into sulphuric acid by means of a porous body, for instance, pumicestone, and that this process may be employed for manufacturing sulphuric acid of 170° Twaddell, without the necessity of leaden chambers or of platinum retorts. This has the advantage of being an immeasurably cheaper material although it can scarcely be so active.

M. BLONDEAU describes another process of the same nature as the last. The author has studied the production of sulphuric acid in certain natural conditions. He instances the Rio Vinagre Pasiambo in

Fig. 598.



position, so that one end was rather higher than the other by about two inches, thus giving it a gentle slope—the use of this will be seen when describing its action.

South America, the water of which, he says, according to an estimate of BOUSSINGAULT, supplies something like thirty-four tons of sulphuric acid in twenty-four hours; and also another instance in which three times this quantity was produced. M. BLONDEAU also examined the production of certain natural sulphates, such as those of potassa, soda, alumina, *et cetera*, and the conditions under which they are produced. Reasoning from his observations, he was induced to try whether certain natural conditions, under which sulphuric acid was produced, could not be imitated in the laboratory; he succeeded in the following manner:—A quantity of argillaceous sand was placed in a porcelain tube laid across a furnace, an apparatus for generating sulphurous acid was attached to one end, together with a tube from a gasometer containing air, and a retort for generating steam. A tube was attached to the other end of the retort, which led into a small vessel containing water, for the purpose of condensing any sulphuric acid which might be formed. The tube was heated red hot, and a slow stream of mixed air, steam, and sulphurous acid was passed through it. At the end of the experiment a quantity of sulphuric acid was found in the condensing flask. M. BLONDEAU suggests this as a mode of making sulphuric acid on the large scale.

WÜHLER has given us the results of some interesting experiments on the production of sulphuric acid by the instrumentality of certain metallic oxides, some acting catalytically, others as simple oxides, yielding up a portion of their oxygen, themselves being converted into lower oxides. He passed a mixture of sulphurous acid and oxygen over several metallic oxides placed in a porcelain tube, and kept at a red heat; but he does not say whether he passed water vapor simultaneously with them. He says that oxide of copper, sesquioxide of iron, and oxide of chromium, each separately employed, instantly caused the production of dense white fumes of sulphuric acid. A mixture of oxide of copper and oxide of chromium, prepared by precipitation, had in particular a very energetic action. The same amount of oxide appeared capable of converting an indefinite quantity of the gases into sulphuric acid. He goes on to say that the production of sulphuric acid proceeds so readily that the process will undoubtedly become practically employed. When sulphurous acid alone is passed over oxide of copper or iron, the first is reduced to red oxide— Cu_2O ,—and the latter to black oxide— Fe_3O_4 ,—with production of sulphuric acid vapors; but which, however, cease to appear as soon as the reduction is complete. WÜHLER gives the reaction of several other bodies; he also states that sulphurous acid, oxygen, and water vapor, passed through a tube alone, do not give rise to any sulphuric acid.

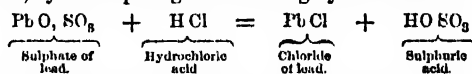
These ideas of WÜHLER appear not to have passed without notice, but on the contrary have been most unceremoniously claimed and patented.

Mr. G. ROHN, in a patent which he obtained, March 26th, 1853, proposes passing sulphurous acid and heated air over the surface of heated sesquioxide of iron—sulphuric acid is the product. He proposes also to take up the sulphuric acid as formed, by passing sulphurous acid mixed with air over a mixture of sesquioxide of iron and common salt—sulphate of soda is formed.

ALFRED TRUMAN obtained a patent for improvements in the manufacture of sulphuric acid when roasting copper ores, *et cetera*. This invention consists in passing the sulphurous acid resulting from the roasting copper ores, mixed with oxygen, atmospheric air, or other suitable material containing oxygen, in contact with heated platinum, oxide of iron, or other substance, having in a heated state the property of causing the combination of sulphurous acid and oxygen. The inventor also claims these bodies when diffused in burnt clay, pumicestone, or other suitable body.

Another process proposed for the manufacture of sulphuric acid is that of M. MARGUERITTE. It is entirely different from any yet described; it consists essentially in the separation of the already formed sulphuric acid from sulphate of lime. It is as follows:—Phosphate of lead is decomposed by hydrochloric acid; the phosphoric acid thus obtained is mixed with sulphate of lime, and the mass is calcined, when phosphate of lime remains and sulphuric acid is expelled. The phosphate of lime is decomposed by boiling with the chloride of lead already obtained, when phosphate of lead is again produced; this is again decomposed by hydrochloric acid, and the phosphoric acid set free again employed in the decomposition of a fresh portion of sulphate of lime. In this process the hydrochloric acid is lost in the form of chloride of calcium. It must consequently always be replaced, but when the sulphuric acid produced is employed in the decomposition of common salt for the production of sulphate of soda, the necessary quantity of hydrochloric acid is always reproduced, with the exception of unavoidable losses. By this process sulphuric acid may be separated from sulphate of baryta and other sulphates. He then proceeds to state that, if necessary, quantities of hydrochloric acid may be obtained from chloride of magnesium by heating it to redness when it is decomposed, especially when mixed with clay. This process is, however, not very likely to come into operation; it would require more hydrochloric acid than the author appears to calculate upon. If the composition of bone earth were CaO PO_4 , there would be a possibility of making vitriol by the reproduced hydrochloric acid.

Sulphate of lead has been patented for the same purpose, by decomposing it with strong hydrochloric acid—

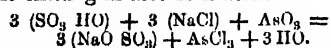


Impurities in Sulphuric Acid.—Sulphuric acid of commerce invariably contains lead. It is not difficult to account for the presence of this body when one reflects how much the acid is in contact with this metal in the chambers, concentrating pans, *et cetera*. Lead always makes its appearance as sulphate when strong acid is diluted with water, the concentrated liquid being able to dissolve a portion of this salt which, when diluted, it is not able to retain. Nitrous compounds are found also, together with traces of hydrochloric acid. Traces of selenium have also been detected. Arsenic is a common impurity, derived usually from the iron pyrites, from which much acid is made. Traces of arsenic have also been detected even in vitriol made from commercial sulphur. Sesquisulphate of iron has also

been found to be present. For the great majority of purposes these impurities are not found inconvenient in the arts; while, on the other hand, for some special uses, a process of purification must be had recourse to.

Purification.—When this is required for analytical or other purposes, distillation must be had recourse to. This, in the case of sulphuric acid, is a disagreeable process, not altogether free from danger, from the violent concussions occurring in the retort. It is usual to put a quantity of strips or fragments of platinum into the acid to obviate this bumping. A very simple condensing arrangement is necessary. The beak of the retort merely requires insertion rather loosely into the neck of a flask or wide tube.

For the purification of sulphuric acid from peroxide of nitrogen, nitric, or arsenious acids, Dr. J. Löwe recommends heating it, in the first place, with oxalic acid. This acid, heated with strong sulphuric acid, becomes first dehydrated, and then, as is well known, decomposes. Carbonic acid and carbonic oxide gases are given off. This carbonic oxide, being in the nascent state, has a strong tendency to deoxidize any highly oxidized body; therefore the peroxide of nitrogen and nitric acid give up a portion of their oxygen, becoming reduced to nitrogen, or nitrous oxide—NO—which bodies are not capable of being retained by the sulphuric acid, and therefore fly off. A temperature of 230° is requisite; at this heat the oxalic acid readily decomposes; it is added to the sulphuric acid, to be purified in small proportions in a dry state, as long as the sulphuric acid continues of a yellow tinge, and until a sample allowed to cool fails to show the presence of nitrous compounds, when heated with protosulphate of iron. The same author proposes eliminating the arsenic from sulphuric acid by converting it into chloride of arsenic, which is very volatile. The vitriol is heated in a flat dish, and small quantities of finely powdered chloride of sodium are added, stirring all the while with a glass rod. The arsenic passes off; the following being the reaction, the arsenic existing as arsenious acid:—



The operation must be conducted under a chimney, or other place where the arsenical fumes will be instantly carried off, so as not to injure the operator.

To avoid the troublesome and dangerous process of distillation, AUGUSTUS A. HAYES proposes to purify sulphuric acid in a very simple manner, namely, by crystallizing it. He first adds a small quantity of salt-petre to the acid while hot, in the leaden pan, and at a density of 1.760. This destroys all organic matter, brownness disappears, and the acid becomes clear. A little sulphate of ammonia is now added, to destroy any excess of nitrate, as well as any nitrous compound already existing in it. The acid is now concentrated to a density of 1.780, and run off into deep vessels of lead, which are allowed to cool to a temperature of 32°; they stand so until clear; they are then run off into shallow lead vessels, so placed that they may become refrigerated to 0°. The acid, which has now nearly the composition $\text{SO}_3 \cdot 2 \text{HO}$, would solidify if allowed to remain long enough; but the vessels must stand only until one half the bulk has

assumed the crystalline state; the mother liquid is then poured off. This mother liquid may be used for any ordinary purposes, such as the decomposition of nitrates, common salt, *et cetera*. The crystals are broken up after being washed with pure acid of a former operation, and are fused in a glass or porcelain vessel, when they form pure sulphuric acid.

Detection and Estimation of Sulphuric Acid.—Sulphuric acid is detected by means of a salt of baryta—this earth being capable of separating it from almost any combination, forming with it sulphate of baryta. In some cases, when testing for sulphuric acid, it is necessary to be very cautious; for instance, when endeavoring to ascertain its presence or otherwise in the nitric or hydrochloric acid of commerce, it is necessary to dilute these acids before adding a salt of baryta. If this is not done the nitrate of baryta, or chloride of barium, will itself be thrown down as a crystalline precipitate, liable to be mistaken for sulphate of baryta; but, if so, the addition of water to the precipitate will cause it to disappear, which will not be the case if the precipitate is sulphate of baryta. This latter salt, being very insoluble in water, furnishes us with a correct method of estimating sulphuric acid; for this purpose a weighed portion of the acid or any of its salts is placed in a beaker glass, and diluted with or dissolved in water. If it is a sulphate, the solution should be made *slightly acid* with nitric or hydrochloric acid, but if it is sulphuric acid alone that is being examined this addition is unnecessary; in either case the liquid is boiled, and, while boiling, a solution of chloride of barium or nitrate of baryta is poured in; the whole is allowed to boil a little longer, when it is removed to cool and settle. A little of the clear liquid above the precipitate is then tested, by the addition of a fresh portion of the baryta salt. If a precipitate is produced, it shows that all the sulphuric acid has not been thrown down, in which case it is necessary to add more of the barytic solution and boil again; if, after settling and further addition of baryta, no precipitate is produced, the whole must be thrown on to a filter, washed carefully with hot water, and dried. It is then ignited in a platinum or porcelain crucible and weighed; 116.6 parts, or one equivalent of sulphate of baryta, are equal to forty-nine parts, or one equivalent of monohydrated sulphuric acid, or forty parts of anhydrous acid. This method would be found too tedious to follow, except on special occasions; ordinarily the manufacturer relies on the indications of his hydrometer—that is, he takes the density for his guide. To enable us to arrive at the real value of the sulphuric acid from the density, several tables have been drawn up, of these. Dr. URE's is commonly used.

AMOUNT OF DRY ACID IN SULPHURIC ACID.

$\text{SO}_3 \text{ HIO}$.	Specific gravity.	SO_3 .
100	1.8485	81.54
99	1.8475	80.72
98	1.8460	79.90
97	1.8439	79.09
96	1.8410	78.28
95	1.8376	77.46
94	1.8336	76.65
93	1.8290	75.83
92	1.8238	75.02
91	1.8179	74.03
90	1.8115	73.39

AMOUNT OF DRY ACID IN SULPHURIC ACID—Continued.

SO ₃ HO	Specific gravity.	SO ₃
89	1.6043	72.57
88	1.7982	71.75
87	1.7870	70.94
86	1.7774	70.12
85	1.7673	69.31
84	1.7570	68.49
83	1.7465	67.68
82	1.7360	66.86
81	1.7245	66.05
80	1.7120	65.23
79	1.6993	64.42
78	1.6870	63.60
77	1.6750	62.78
76	1.6630	61.97
75	1.6520	61.15
74	1.6415	60.34
73	1.6321	59.52
72	1.6204	58.71
71	1.6090	57.89
70	1.5975	57.08
69	1.5868	56.26
68	1.5760	55.45
67	1.5648	54.63
66	1.5503	53.82
65	1.5390	53.00
64	1.5280	52.18
63	1.5170	51.37
62	1.5066	50.55
61	1.4960	49.74
60	1.4860	48.92
59	1.4760	48.11
58	1.4660	47.29
57	1.4560	46.48
56	1.4460	45.66
55	1.4360	44.85
54	1.4265	44.03
53	1.4170	43.22
52	1.4073	42.40
51	1.3977	41.58
50	1.3884	40.77
49	1.3788	39.95
48	1.3697	39.14
47	1.3612	38.32
46	1.3530	37.51
45	1.3440	36.69
44	1.3345	35.83
43	1.3255	35.06
42	1.3165	34.25
41	1.3080	33.43
40	1.2999	32.61
39	1.2913	31.80
38	1.2826	30.98
37	1.2740	30.17
36	1.2654	29.35
35	1.2572	28.54
34	1.2490	27.72
33	1.2409	26.91
32	1.2334	26.09
31	1.2260	25.28
30	1.2184	24.45
29	1.2108	23.65
28	1.2032	22.83
27	1.1956	22.01
26	1.1876	21.20
25	1.1792	20.38
24	1.1706	19.57
23	1.1626	18.75
22	1.1549	17.94
21	1.1480	17.12
20	1.1410	16.31
19	1.1330	15.49
18	1.1246	14.68
17	1.1165	13.86
16	1.1090	13.05
15	1.1019	12.23
14	1.0953	11.41
13	1.0887	10.60
12	1.0809	9.78
11	1.0743	8.97
10	1.0682	8.15
9	1.0614	7.34
8	1.0544	6.52
7	1.0477	5.71
6	1.0405	4.89

AMOUNT OF DRY ACID IN SULPHURIC ACID—Continued.

SO ₃ HO	Specific gravity.	SO ₃
5	1.0336	4.08
4	1.0268	3.26
3	1.0206	2.45
2	1.0140	1.63
1	1.0074	0.82

In this table there is opposite a list of different densities, the quantity of dry acid per cent., either dry or monohydrated. To bring the degrees of TWADDELL's hydrometer to those of the real specific gravity, it is only necessary to multiply the first by five, and add one thousand; thus, supposing a sample of vitriol to stand 150° on TWADDELL's hydrometer, multiply this 150° by 5°, and one has 750°; to this add 1000°, and the specific gravity, 1.750° is obtained. Now, to ascertain the amount of real sulphuric acid in this sample, it is only necessary to run through the table and find the density 1.750°, or the nearest approach to it, which in this case is 1.746°. It will be found then that the sample would contain eighty-three per cent. of the monohydrated acid, or 67.68 per cent. of dry acid.

This method of arriving at the value of a sample, though very convenient, is liable to error; for instance, the sample might contain foreign matter dissolved in it; this would augment the density, and cause it to appear of more value than it really is. A slight change of temperature also will alter the density considerably. The following table, the production of Mr. PARKES, shows the gradual lowering of the density as the temperature increases, so that, even though the sample may be free from foreign bodies, error may creep in. From this table it is evident, that the density of all samples of vitriol should be taken, as in the case of Dr. URE's table, at as near as possible 60°.

PARKES'S TABLE OF VARIATIONS IN DENSITY OF CONCENTRATED SULPHURIC ACID THROUGH CHANGE OF TEMPERATURE.

Temperature Fahrenheit	Density.
30°	1.8593
32	1.8563
36	1.8546
38	1.8532
40	1.8527
42	1.8520
44	1.8522
46	1.8510
48	1.8517
52	1.8511
56	1.8500
60	1.8468
63	1.8449
68	1.8435
70	1.8430
74	1.8413
80	1.8381
84	1.8343

Again, when the density of a sample is high, it is difficult to estimate it with sufficient accuracy. If one examine Dr. URE's table, he will find that acid of 1.8439 specific gravity contains ninety-seven per cent. of monohydrated acid, while the density of the monohydrated acid itself is but 1.8486—thus the slight difference of .0046, or rather less than one degree on the hydrometer, equals three per cent. To obviate this, Dr. DALTON proposed that the boiling point should be taken as the guide, instead of the specific gravity, inasmuch as it permits a range of ten or twelve degrees for one per cent. of real acid. For this purpose he drew up the following table:—

DR. DALTON'S TABLE OF BOILING POINTS OF SULPHURIC ACID AT DIFFERENT STRENGTHS.

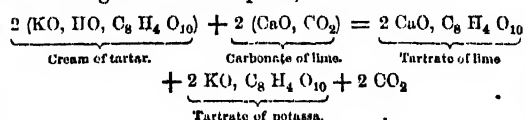
Specific gravity.	Dry acid per cent.	Boiling point.
1.850	81	620°
1.849	80	605
1.848	79	590
1.847	78	575
1.845	77	560
1.842	76	545
1.838	75	530
1.833	74	515
1.827	73	501
1.819	72	487
1.810	71	473
1.801	70	460
1.791	69	447
1.780	68	435
1.769	67	422
1.757	66	410
1.744	65	400
1.730	64	391
1.715	63	382
1.699	62	374
1.684	61	367
1.670	60	360
1.650	58.6	350
1.520	40	290
1.408	40	260
1.300	30	240
1.200	20	224
1.100	10	218

In addition to these methods, there may be mentioned that of testing the value of vitriol by an acidimetric process, with a standard solution of alkali.

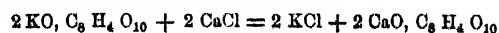
Mr. PETER HART, of Manchester, kindly supplied some valuable information which the Editor has incorporated in this monograph.

TARTARIC ACID— $2\text{HO}, \text{C}_6\text{H}_4\text{O}_{10}$ —*Acide tartarique*, French, *Weinsteinsäure*, German—was first obtained in a separate state by SCHÉELE in 1770. It is found partly free, partly combined with bases in many plants. It exists most largely in grape-juice, but it is met with also in tamarinds, and the berry of the mountain ash; in madder, potatoes, cucumbers, quassia, squills; in mulberries, pine apples, &c. &c.

Preparation.—In order to prepare the acid, four parts of crude tartar—*argol*—are suspended in boiling water, and one part of chalk added. As soon as the effervescence entirely ceases, and the liquid no longer reddens litmus, the tartrate of lime is allowed to settle at the bottom, and the clear tartrate of potassa decanted. The change which takes place, is as follows:—

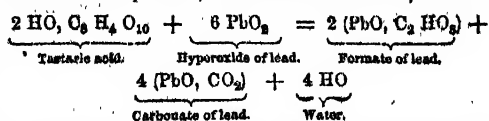


The dissolved tartrate of potash may be further decomposed by chloride of calcium: thus—

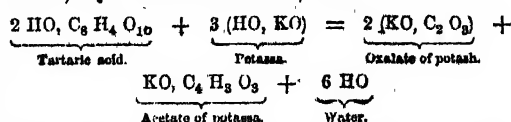


The well-washed precipitates are digested with sulphuric acid diluted with ten parts of water, five parts of the tartar employed requiring three parts of the acid. Sulphate of lime is formed, and tartaric acid set free. On evaporating the filtered solution in leaden vessels to the consistence of sirup, tartaric acid crystallizes in large, transparent, colorless, oblique rhombic prisms of agreeable sour taste, and specific gravity 1.75; is readily soluble in water and alcohol; unalterable in air. When greatly heated, the crystals become strongly electrical.

Boiled with nitric acid, tartaric acid is decomposed into acetic, oxalic, and saccharic acids. Boiled with hyperoxide of lead, it becomes oxidized and changed into formate of lead, water, and carbonate of lead, thus—



If heated with alkalis, a mixed oxalate and acetate results, with evolution of water, thus—



Mixed with spongy platinum and heated in a stream of oxygen, tartaric acid is at 482° completely resolved into carbonic acid and water.

The action of heat upon tartaric is as instructive as it is remarkable.

It melts between 338° and 356°, and without losing weight is changed into a mixture of two acids—metatartaric with tartaric acid.

METATARTARIC ACID— $\text{C}_8\text{H}_6\text{O}_{12}$; or $2\text{HO}, \text{C}_8\text{H}_4\text{O}_{10}$ —forms a transparent vitreous mass. It is bibasic, but its salts are more soluble than the corresponding ones of tartaric acid.

ISOTARTARIC ACID— $\text{HO}, \text{C}_8\text{H}_5\text{O}_{11}$ —is monobasic. Its salts are isomeric with the bitartrates, but very much more soluble. Solutions of isotartrates as well as of metatartrates are changed by boiling into tartrates.

If tartaric acid be heated to 374° it fuses: two equivalents lose one equivalent of water and become changed into an acid, called by FRÉMY, **TARTRELIC ACID**— $3\text{HO}, \text{C}_{16}\text{H}_8\text{O}_{20}$.

If the heat be still longer continued tartaric acid loses half its basic water and becomes **TARTRELIC ACID**— $2\text{HO}, \text{C}_{16}\text{H}_8\text{O}_{19}$.

Most probably both tartrallic and tartrellic acids are mere combinations of anhydrous tartaric acid with varied proportions of crystallized tartaric acid.

If the heat—374°—be carefully maintained for yet a longer time, **ANHYDROUS TARTARIC ACID** or **TARTARIC ANHYDRIDE** remains in form of a white, porous mass insoluble in water. Adherent tartrellic acid is removed by washing with water till the wash liquor no longer reddens litmus. By contact with cold water for a few hours anhydrous tartaric acid resumes its basic water.

Small quantities of tartaric acid are completely decomposed in an oil-bath at 512°, leaving only a slight carbonaceous residue.

Tartaric acid is much used by dyers and calico-printers for the removal of certain mordants from portions of the cloth. It is also used in preparing effervescing draughts. In the blood, tartrates are changed into carbonates.

Aqueous solutions of tartaric acid, especially when hot, exercise right-handed rotation upon polarized rays of light—the angle of deviation corresponds to the quantity of acid traversed by the ray.

Tartaric acid is *bibasic*; its salts are tartrates.

BITARTRATE OF POTASSA— $\text{KO}, \text{HO}, \text{C}_6 \text{H}_4 \text{O}_{10}$ —is the *cream of tartar* or *argol* of commerce, and is obtained chiefly as an incrustation from the inside of wine casks. It crystallizes in hard, opaque, oblique rhombic prisms, of snowy whiteness when pure, and of sour taste; soluble in one hundred and eighty parts of cold and six of boiling water; in alcohol nearly insoluble. Heated to redness in close vessels, a mixture of carbonate of potassa and charcoal results—much used as *black flux*. Calcined with its own weight of nitre, *white flux*, or carbonate of potassa, is obtained.

NEUTRAL TARTRATE OF POTASSA— $2 \text{KO}, \text{C}_6 \text{H}_4 \text{O}_{10}$ —by slow evaporation in transparent, colorless prisms, somewhat deliquescent, and very soluble.

BITARTRATE OF SODA— $\text{NaO}, \text{HO}, \text{C}_6 \text{H}_4 \text{O}_{10}$, 2HO —in transparent, colorless, right rhombic prisms, from a hot solution of the neutral salt, mixed with half its weight of tartaric acid.

NEUTRAL TARTRATE OF SODA— $2 \text{NaO}, \text{C}_6 \text{H}_4 \text{O}_{10}$, 4HO —soluble in five of cold and half their weight of boiling water. In transparent, colorless, right rhombic prisms.

NEUTRAL TARTRATE OF POTASSA AND SODA— $\text{KO}, \text{NaO}, \text{C}_6 \text{H}_4 \text{O}_{10}$, 8HO —is *Rochelle salt*, obtained by neutralizing cream of tartar with carbonate of soda. In large, transparent, colorless, right rhombic prisms, soluble in 2.62 parts of water at 42° . The salt is medicinal.

BITARTRATE OF LITHIA— $\text{LO}, \text{HO}, \text{C}_6 \text{H}_4 \text{O}_{10}$, 3HO —in small crystals, very soluble in water.

NEUTRAL TARTRATE OF LITHIA— $2 \text{LO}, \text{C}_6 \text{H}_4 \text{O}_{10}$ —white, opaque, deliquescent.

BITARTRATE OF AMMONIA— $\text{NH}_4\text{O}, \text{HO}, \text{C}_6 \text{H}_4 \text{O}_{10}$ —in delicate needles, but little soluble in water. The crystals are in form of oblique rhombic prisms.

NEUTRAL TARTRATE OF AMMONIA— $2 \text{NH}_4\text{O}, \text{C}_6 \text{H}_4 \text{O}_{10}$ —in oblique prisms, readily soluble, and with a taste like that of nitre.

NEUTRAL TARTRATE OF POTASSA AND AMMONIA— $\text{KO}, \text{NH}_4\text{O}, \text{C}_6 \text{H}_4 \text{O}_{10}$ —in transparent, colorless prisms, isomorphous with neutral tartrate of potash.

NEUTRAL TARTRATE OF BARYTA— $2 \text{BaO}, \text{C}_6 \text{H}_4 \text{O}_{10}$ —a crystalline powder, soluble in eight hundred parts of cold water.

NEUTRAL TARTRATE OF STRONTIA— $2 \text{SrO}, \text{C}_6 \text{H}_4 \text{O}_{10}$, 8HO —soluble in one hundred and forty-seven parts of water at 60° .

BITARTRATE OF LIME— $\text{CaO}, \text{HO}, \text{C}_6 \text{H}_4 \text{O}_{10}$ —in the fruit of *Rhus typhinum*, in crystals, sparingly soluble in water.

NEUTRAL TARTRATE OF LIME— $2 \text{CaO}, \text{C}_6 \text{H}_4 \text{O}_{10}$ —occurs in grapes, and mixed with crude tartar; also in senna leaves. Neutral tartrate of potassa forms, with chloride of calcium, a crystalline precipitate—it is the salt obtained in making tartaric acid. Crystals, right rhombic prisms with octahedral summits; soluble in twelve hundred parts of cold water.

BITARTRATE OF LIME— $\text{CaO}, \text{HO}, \text{C}_6 \text{H}_4 \text{O}_{10}$ —in the fruit of *Rhus typhinum*. The crystals dissolve in one hundred and forty parts of water and redden litmus.

NEUTRAL TARTRATE OF MAGNESIA— $2 \text{MgO}, \text{C}_6 \text{H}_4 \text{O}_{10}$, 8HO —obtained by digesting excess of magnesia alba in dilute tartaric acid. Crystalline crusts

soluble in one hundred and twenty-two parts of cold water. Like tartrate of lime, the residue by ignition is pyrophoric.

BITARTRATE OF MAGNESIA— $\text{MgO}, \text{HO}, \text{C}_6 \text{H}_4 \text{O}_{10}$ —when excess of acid is employed. Six-sided prisms soluble in fifty-two parts of cold water.

TARTRATE OF ALUMINA occurs in *Lycopodium clavatum*. Very soluble.

TARTRATE OF LEAD— $2 \text{PbO}, \text{C}_6 \text{H}_4 \text{O}_{10}$ —by precipitating neutral acetate of lead with tartaric acid. A white crystalline powder, almost insoluble in water.

PROTOTARTRATE OF IRON is made from iron filings and dilute tartaric acid, with exclusion of air. A white powder requiring four hundred and twenty-six parts of cold water for solution. It is said to contain thirteen per cent. of water.

PERTARTRATE OF IRON, by dissolving the freshly prepared hydrated peroxide of iron in solution of tartaric acid. Its solution is not precipitated by alkalis.

POTASSO-TARTRATE OF IRON— $\text{KO}, \text{Fe}_2 \text{O}_3, \text{C}_6 \text{H}_4 \text{O}_{10}$ —is an important medicinal salt. It is obtained by digesting the hydrated sesquioxide of iron with water, and bitartrate of potassa at 125° for twenty-four to thirty-six hours, and evaporating the residue on plates. In lustrous scales of dark brown color.

AMMONIO-TARTRATE OF IRON— $\text{NH}_4, \text{Fe}_2 \text{O}_3, \text{C}_6 \text{H}_4 \text{O}_{10}$, 4HO . Made like the previous salt, with substitution of bitartrate of ammonia. It is quite stable in composition when its solution is boiled.

TARTRATE OF COPPER— $2 \text{CuO}, \text{C}_6 \text{H}_4 \text{O}_{10}$, 6HO —by precipitation of acetate of copper with tartaric acid. A very light blue powder, soluble in one thousand seven hundred parts of cold water.

POTASSO-TARTRATE OF COPPER— $\text{KO}, \text{CuO}, \text{C}_6 \text{H}_4 \text{O}_{10}$ —by boiling oxide of copper in solution of cream of tartar. Crystals dark blue; very soluble.

TARTRATE OF SILVER— $2 \text{AgO}, \text{C}_6 \text{H}_4 \text{O}_{10}$ —by mixing neutral tartrate of potash or Rochelle salt with nitrate of silver. A white, crystalline, lustrous powder; gently heated, spongy silver remains, with evolution of pyrotartaric and carbonic acids.

POTASSO-TARTRATE OF ANTIMONY— $\text{KO}, \text{SbO}_3, \text{C}_6 \text{H}_4 \text{O}_{10}$, HO —is extensively used in medicine under the name of *tartar emetic*. Three parts of oxide of antimony are made into a thin paste with water, and mixed with four parts of bitartrate of potassa. The mixture is digested for several hours, and then boiled with eight parts of water. The boiling-hot solution is filtered and allowed to crystallize. Transparent or opaque, colorless, shining rhombic octahedra, of metallic taste. It is soluble in fifteen parts of cold and two of boiling water. In small doses it is an emetic; in larger doses it is a poison.

Of the heavy metals, iron is the only one which precipitates antimony completely from the aqueous solution of tartar emetic. Hydrochloric, nitric, and sulphuric acids precipitate a basic hydrochlorate, nitrate, and sulphate of the oxide of antimony.

There are several other antimonial tartrates, the place of potassa being supplied by soda, ammonia, lead, oxide, and silver oxide. A compound similar to tartar emetic may be formed with arsenious acid— $(\text{KO}, \text{AsO}_3, \text{C}_6 \text{H}_4 \text{O}_{10})$.

TIN.—*Etain*, French; *zinn*, German; *stannum*, Latin.—Tin is the *Jupiter* of the alchemists. It is one of the metals which were known to the ancients, and is evidently of high antiquity, although, in all probability, gold, silver, copper, and iron were known much sooner. It is supposed by some that the original Hebrew term *bedil* of Holy Writ indicates this metal; but others infer that a compound or mixture resulting, perhaps, from the purification of gold and silver possessing an inferior value, was meant by it. Under the impression that the word above mentioned denoted tin, the Greek translators of the scriptures rendered it *κασσίτερος*; by which term the classic writers of profane history describe tin, after all doubt had been removed as to its identity. BECKMAN discusses the question whether the *stannum* of the Latins and the *κασσίτερος* of the Greeks was really the metal which forms the subject of the present article; and whilst he leaves the point undecided, advances various arguments to show that a rich alloy of silver and lead was frequently, if not always, the substance indicated by the foregoing titles.

Whatever may have been the nature of such alloys, it is certain, from the writings of DIOSCORIDES, DIODORUS, PLINY, and others, as well as from Celtic records, that tin was known at a very early period. It is recorded that between 1040 and 1030 before the Christian era, the Phœnicians had discovered that part of Britain known at present as Cornwall and Devon, and instituted searches for minerals and metals therein; and the active exportation of the metals—principally tin—led to the adoption of the title *Breotan*—red or burning fires and land—for the mainland, from the circumstance of large fires being kept burning on all the bold heights of the country to serve as beacons for the mariners along the dangerous coast; of which words Britain is but a slight modification. The metal tin was called in the dialect of the people of Phœnicia *stîn*, whence the *stannum* of the Romans; from this root likewise has been derived the title *Stanneries*, which is still applied in Cornwall to the districts where tin is produced.

That the quantity of tin extracted from the British mines was considerable, is very evident even from the account of the Greek writers already alluded to; thus DIODORUS, in the second chapter of his fifth book, says—The inhabitants of that part of Breo-tan—Britain—called *Bolerion*—supposed to be the Land's-end, but actually a corruption of *Bal-erig*, which means the country of the *Erians* or *Iberians*, of which it is an abbreviation—excel in their hospitality; and also, from their converse with merchants, they are more civilized and courteous to strangers. These are the people who make the tin, which, with a great deal of care and labor, they dig out of the ground which is rocky; but it has in it earthy veins, the produce of which is brought down, melted, and purified. Then when they have cast it into the form of cubes, they carry it to an island adjoining to Britain called *Iktis*. During the recess of the tide the intervening space is left dry, and the tin is carried to the island in carts; and it is something peculiar that happens to the islands in those parts lying between Europe and Britain, for at full tide, the passage being overflowed, they appear islands; but when the

sea returns, a large space is left dry, and they are seen as peninsulæ. From this the tin is transported to Gaul, through which it is conveyed on horseback in about thirty days to the mouth of the river Rhone.—*Diodorus*.

The island above alluded to will be at once recognized as one of the Scillies, and its Greek name was probably derived from its being made a fishing-station by the Phœnicians.

Of the mode of operations by which the tin was extracted, or the mines worked in those days, no record is left; but from the remains which have been discovered, it is conjectured that the methods adopted were of the rudest description. By whatever means the mining and metallurgy of tin were prosecuted in Cornwall and Devon up to the period of the Norman conquest, it is certain that after that event they received a great impetus, so that the chief part of the revenues of the Earls of Cornwall was derived from it. King John gave a charter to the Cornish tin mines in 1201; another was granted them in 1305 by Edward I., and the stannery laws were instituted in his reign. These laws are still extant, and partly in force; but want of space forbids a full account of them here. Previous to the thirteenth century England enjoyed a monopoly of the tin trade; but in that age rich veins of tin ore were discovered in Misnia and Bohemia; and about the year 1250 the English trade was much reduced by the low price at which the Germans were able to sell their tin. At present tin is found in several places, and mines of it are wrought in Bohemia, Saxony, and Austria; in Galicia, on the borders of Portugal; at Piriac, in the *Loire inférieure*; and at Vaulry, in the department Haute Vienne in France; but the mines of French localities are of very little importance. Large quantities of tin ore occur in the Siberian mining district of Nertschinsk, and it is found in Dalecarlia in Sweden; but the richest deposits that have hitherto been found are those in the province of Tenasserim on the east side of the Gulf of Martaban in the Malayan peninsula; these have been worked for many centuries, and considerable quantities are still obtained. In the early part of the last century—1710—large quantities of very pure ore of tin were discovered in the island of Banca, whence as much as three thousand five hundred tons of the metal have some years been abstracted. Minerals of tin exist also in Brazil, in Mexico and Chili, in South America, in the United States, and Australia. The tin mining districts of Cornwall and Devonshire are three in number; namely, that included in the South-west of Cornwall beyond Truro, the neighborhood of St. Austell, and of Tavistock in Devonshire. The chief tin mines in these districts are Wheal Vor, near Helston; Polberrow, near St. Agnes; Polgooth, near St. Austell; Drake Walls, near Tavistock, on the Cornish side of the Tamar; and Birch Tor, also near Tavistock, but on the Eastern side in Devonshire. Ores of tin are found in all the localities mentioned, either in the form of regular lodes or veins disseminated in granite and in felspar—porphyry or elvan—and in alluvial formations on the slopes of hills, or in the valleys. In the former instances, the veins frequently cross one another either horizontally or in their perpendicular descent; occasionally they ramify through the rock in all directions,

producing at the point of intersection masses of ore called by the Germans *stockwerk*, such as the Altenberg mine in Saxony. In the other instance of the occurrence of tin ore, namely, in alluvial deposits, it is usually called *stream tin*, as well from the nature of the deposit, as from the fact that in these cases the workings are generally in the course of rivulets or streams. It is found either in a pulverized sandy state, in separate stones, called *shodes* in Cornwall, or in a continued course of stones, which are sometimes found together in large numbers, and at depths varying from one to fifty feet. The course of these deposits is called a stream; but they have little regularity, varying in their breadth, and are scattered over the entire extent of the moor or valley in which they are found. *Wood tin*, the name given to pebbles of ore having a woody appearance, though now rather scarce, was formerly found in some of the stream-works of Cornwall.

MINERALS OF TIN.—Tin is found almost invariably in the form of binoxide of tin or tin-stone, and in some instances associated with iron and copper pyrites, forming what is called tin pyrites or bell-metal ore, but the quantity so existing is very small.

BINOXIDE OF TIN.—*Cassiterite*; *tin-stone*; *zinnstein*.—This ore of tin, from which almost the whole of the metal is smelted, is found, as already mentioned, in different states of aggregation. It is characterized by a high gravity, averaging 6.3 to 7.1, adamantine lustre, and color varying from a brown or black to various shades of red, yellow, grey, and white. In crystalline shape it belongs to the right prismatic system, the crystals being twins, with some of the faces uneven, and others striated parallel to their intersections with each other. The crystals have but a very imperfect cleavage, their fracture is imperfectly conchoidal and their streak grey, and sometimes brown. Heated before the blowpipe, oxide of tin remains infusible *per se*; with soda in the reducing flame it affords small globules of metal. Acids do not exert a solvent action upon it, and therefore it cannot be dissolved till after its fusion with alkalis. In its pure state binoxide of tin contains—

	Atomic weights	Centesimally.
1 Eq. of tin,	59	78.06
2 Eqs. of oxygen,	16	21.94
	75	100.00

Samples of the ore have been analyzed, and the results are stated thus—

	From Altenberg in Cornwall, by Klaproth.	From Schlacken- wald, by Klaproth.	From Pilsen, near Friburg, by Berzelius.
Oxide of tin,	98.93	99.28	93.6
Red oxide of iron, ...	0.32	0.72	1.4
Silica,	0.75	—	—
Columbic acid,	—	—	2.4
Binoxide of manganese	—	—	0.8
	100.00	100.00	98.2

This ore is found in the various localities already referred to, accompanied with quartz, mica, fluorspar, apatite, topaz, tourmaline, wolfram, heavyspar, mispickel in the lode; and in the alluvial beds of valleys and plains.

TIN PYRITES—*stannin*; *zinnkies*.—This ore of tin occurs in a few of the Cornish mines, such as those

of Huel Rock in St. Agnes, and some of the granite veins in St. Michael's Mount; also at Zinnwald in Bohemia. Its crystalline form is cubic; the cleavage of the crystals is imperfect, the fracture uneven and conchoidal, the lustre metallic, with a steel-grey, inclining to bronze-yellow color, and a black streak. The specific gravity is 4.3 to 4.51.

Before the blowpipe on charcoal it melts in a strong heat, turns white on the surface, and deposits a fixed sublimate of binoxide of tin round the assay. After roasting, it affords, with the usual fluxes, the peculiar reactions of iron and copper, and a brittle globule of the latter metal on fluxing with soda and borax. Nitric acid decomposes it, dissolving the iron and copper, and leaving a deposit of sulphur and of binoxide of tin. The following analyses indicate the composition of a few samples of this ore; samples A and B from Huel Rock; C from St. Michael's Mount, and D from Zinnwald:—

	Klaproth.		Johnston.	Rammelsherg.
	A	B	C	D
Copper,	30.00	29.69	23.55	26.31
Iron,	12.00	12.57	4.79	6.80
Zinc,	—	1.79	10.11	6.93
Tin,	26.50	25.81	31.62	28.94
Lead,	—	—	—	0.41
Sulphur,	30.50	29.95	29.93	29.89
Loss,	1.00	0.19	—	0.72
	100.00	100.00	100.00	100.00

PREPARATION OF TIN.—The reduction of the ore is effected by roasting and smelting, in a manner similar to that which will be described further on, and the button so obtained is then treated in the following manner, to separate the metal from the arsenic, antimony, bismuth, zinc, lead, iron, and copper, one or more of which it may contain; or ordinary commercial tin may be taken for this purpose.

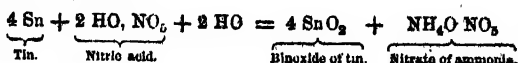
In either case the crude metal is treated with an excess of hydrochloric acid, when the tin, zinc, bismuth, copper, and iron are dissolved, whilst the arsenic and antimony will be separated; the former volatilized in the form of terhydride of arsenic, and the latter partly deposited as a black powder in the liquid, and partly dispelled as antimonide of hydrogen. The solution is filtered, and the liquid concentrated at a boiling temperature, and strong nitric acid in excess added, after which the evaporation is continued to dryness. The tin is thus obtained in the state of binoxide, which should be treated with a little hydrochloric acid, then filtered, washed thoroughly, and dried, mixed with charcoal, and reduced at a white heat in a charcoal-lined crucible.

Properties.—Tin is a white metal, having a metallic lustre, approximating to that of silver; it is softer than gold, but harder than lead, and has a specific gravity of 7.291. It is very malleable, so much so that it can be rolled into sheets of not more than the one-thousandth of an inch in thickness, but wanting ductility and tenacity to any useful degree. A wire of the metal, 0.7 of an inch in diameter, will sustain only thirty-four and a half pounds weight. Tin melts at 442°, and contracts slightly on cooling; at a strong red heat it emits white fumes, but the tension of its vapor is

very feeble, and therefore little loss of metal is sustained. The metal exhibits a great tendency to crystallize when a mass of it is melted in a covered crucible, and allowed to cool very slowly; if before the bulk has solidified the fluid portion be poured off, the hardened part remaining in the vessel will be found crystallized in rhombic plates, according to PAJOT; and in octagonal needles, according to BROOKE. This tendency to crystallize is readily exhibited by dissolving the exterior coating of a plate of the metal by means of moderately dilute aqua-regia, and then washing off the acid with water. The surface will then exhibit a mottled appearance, owing to the irregular reflection of the fern-like crystals which the action of the acid reveals. Various pretty designs are in this way formed on the surface of moderately thick tinned plates; and the French, who practise the process for decorating snuff-boxes, *et cetera*, call it *moire metallique*. It is to the crystalline arrangement of the particles of the metal that the crackling sound which a bar of it emits on being bent backward and forward is due, the decapitation being produced by the displacement of the small crystals of which the bar is composed. By repeatedly inducing this friction an amount of caloric is developed, which can be readily detected by a sensible calorimeter.

Tin retains its brilliancy for a considerable time when exposed to the air; when heated in the air to the melting point, however, it is immediately covered with a film of oxide of tin; and if the heat be increased, the oxidation of the metal becomes so rapid as to induce ignition. In both instances binoxide of tin results. The same change takes place when steam is passed over a bath of the metal heated to redness out of contact of air; for the metal abstracts the oxygen of the water, and sets free the hydrogen. Tin combines with most of the metalloids, producing generally two orders of combination, distinguished by the terms proto or stannous, and binary or stannic, compounds of such elements with the metal. The combination with many of these, as with sulphur, bromine, iodine, chlorine, *et cetera*, is so intense that, at a slightly elevated temperature the metal enters into active combustion, whilst the stannic salts of these radicals are produced. Acids have likewise a well-marked action upon it; for instance, hydrochloric acid, at the ordinary temperature, slowly dissolves it, with evolution of hydrogen; at a boiling temperature the action is much more active; in both reactions the stannous chloride is formed. Dilute sulphuric acid, with the aid of heat, converts it slowly into a sulphate of the protoxide, and liberates hydrogen; the concentrated acid has little or no effect upon it in the cold, but if the liquid be heated to the boiling point, it rapidly attacks the metal, sulphurous acid being liberated. Slips of bright tin-foil, immersed in concentrated nitric acid, experience no change, however long they may be

retained in it; but if the acid be diluted with water, the action becomes violent, owing to the rapid conversion of the metal to a binoxide of modified properties, known as metastannic acid, and the evolution of binoxide of nitrogen. If the nitric acid be previously diluted, no nitrous fumes are given off during the oxidation of the metal, but nitrate of ammonia is formed, thus—



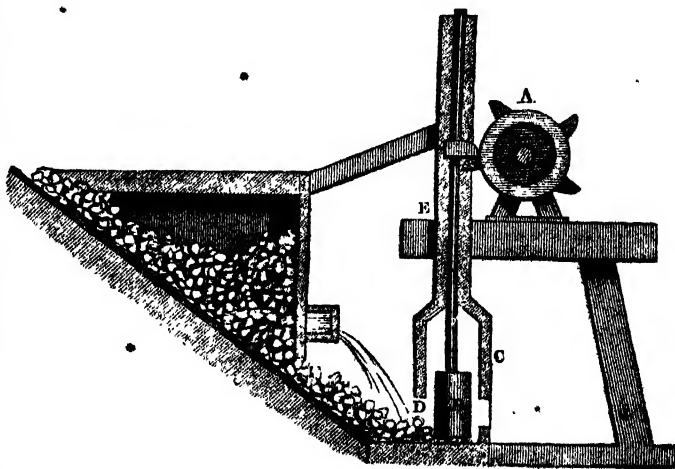
The fixed caustic alkalis dissolve tin, and produce with it a compound in which the combination of this metal takes the character of a salt radical; in this case water is decomposed and its oxygen is assimilated by the tin, whilst the hydrogen is given off.

The symbol for tin is Sn; its equivalent number 59.

METALLURGY OF TIN—Preparation or Dressing of the Ore.—In preparing ore of tin for the smelter, much pains are taken for the separation of all earthy matters and metallic substances that would reduce the percentage yield of the ore, or injure the quality of the tin when smelted. The order in which this dressing is performed is much the same as when copper ores are under treatment—namely, *cleaning and sorting of the ore, stamping and washing*, and, finally, *calcination and washing*.

Sorting the Ore.—This operation is commenced on the surface by washing away the clay and light impurities from the ore by a stream of water, and breaking or *spalling* the stones containing the ore, and separating the whole into heaps of different qualities and classes, according to the nature of the gangue, or the other minerals accompanying the tin; thus ores containing copper and iron pyrites are classed differently from such as contain only earthy matters, and such as contain tungsten are set aside by themselves to be submitted to a special treatment. The richest and

Fig. 599.



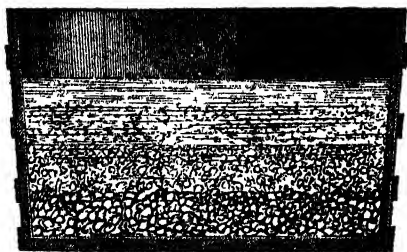
purest lumps are placed together in heaps on the dressing floor, and are called *best work*; the second quality, though less rich than the preceding, are

nevertheless remunerative; and the third division consists of matter that is very poor in, if not wholly without, ore.

The several heaps of ore are further reduced by the stamping mill to a fine powder. This *machine* is shown in section in Fig. 599. It consists of a wooden shaft, connected with a water-wheel or steam-engine, in which are arranged a number of cams that catch upon the lifting arms of a series of pestles heavily shod with iron, and secured in a strong wooden box lined with iron to prevent the dispersion in all directions of the ore by the strokes of the pestles or stamps. In the figure, A indicates the revolving shaft with the cams, B the pestle, and C the box confining them, D the ore to be crushed, and E a sluice which supplies a stream of water that carries off the reduced ore to the tanks along narrow inclined planes. Four stamping heads, averaging two and a half to three and a half hundredweight each, are worked in each box, and in the following order:—The pestle to the left of the spectator, supposed to be standing in front, first; the extreme right second; the right middle one third; and the left middle last—and each pestle is so lifted that the strokes follow in succession. The revolving shaft makes about twenty revolutions per minute, and the ore which enters the box receives from one hundred and sixty strokes to double this number to reduce it. The stream of water, entering the box from E, conveys the reduced ore, aided by the force of the pestles, through gratings at the ends and sides of the box to the inclined plane or cistern already mentioned. Here the ore, in consequence of its gravity varying in the ratio of its contents of metal, arranges itself into three kinds—the heaviest, and therefore the richest, resting on the upper part; a less rich ore in the middle; and the poorest or gangue parts—the tailings—at the lowest part. Very fine portions of the ore are carried off by the water in suspension to the slime pits, where it settles to the bottom, to be occasionally collected. The richest portion of the ore on the inclined plane is removed to the rectangular *buddle*, where it is washed under a regular stream of water, the ore being kept by a brush spread equally over the floor of the buddle. In this way the material is further purified, the richer ore remaining on the upper half of the table, and a poorer product on the lower half.

The richer ore is further purified in the *liver*, or tos-

FIG. 600.



ing tub—Fig. 600. It consists simply of a stout wooden vat, well bound with iron hoops, having a capacity of a hundred gallons or more. A quantity of the purer

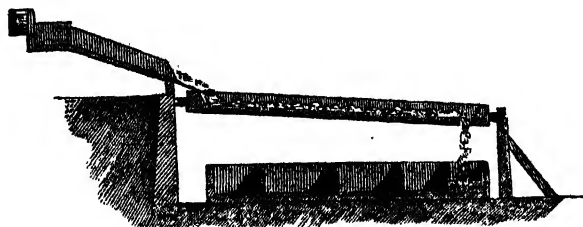
ore, from the buddle in the preceding instance, together with a quantity of water, is thrown into the tub and stirred well up with a shovel for a few minutes, and then allowed to rest, while to expedite the subsidence of the ore, the workman strikes the tub all round with a hammer. Here, again, a further separation of the ore takes place, according to the order of its gravity, the richer kinds being nearer the bottom of the tub, and forming distinct layers, as shown in the figure. The top layer is thrown away as being of little value, or is reserved for further washing in the circular buddle with other portions of poor ore; the second is submitted to another washing; and the lower layer is fit for the smelting furnace or the roaster, if it be pyritous, and is called *tin witts*.

The matter on the middle of the inclined plane or cistern adjoining the stamping mill is delivered into a wooden trough placed over the cistern, and washed by a small stream of water direct into the circular buddle, where the washing of ore is effected in larger quantity, and at less expense than in washing the rich ore as it becomes separated. Several of these circular buddles are required, and the lower layer of the deposit in one is conveyed by a trough to the next, and there washed. In this way the richer parts are removed from the poorer tailings; and when they arrive at the proper standard they are removed, and their cleansing finished on the rectangular buddle and tossing tub, as described. The contents of the slime pits are purified, first, by what is known as the *trunking process*, and secondly, on the *racking table*. The trunking box consists of a long sloping cistern, with a division near its upper end, forming a small quadrangular vessel, in which the ore, slime, and water are delivered. The contents of this small cistern are agitated by the slow movement of a paddle placed in it, and thus portions of slime and water are thrown out into the sloping trunk at each stroke. As it flows down this incline the heavier ore first separates, and continues to deposit, according to its density, towards the end of the trunk, where, however, the matter collected is of little worth. When enough of the mud is thus treated to fill the long cistern, the admission of more of the sludge is prevented, and the higher portion of the deposit is transferred to the *racking tables*, whilst the other portion is again submitted to the preceding trunking process. The racking table, shown in Fig. 601, is a long wooden table, set at an incline of one in sixteen, and having shallow bevelled flanges at the sides and ends to serve as a frame for it, and supported by centre pivots on a wooden framework about three feet high. At the head of the table is fixed the sloping board, hinged to it with leather, and upon this the mixture of ore and water is delivered, and a number of boxes, generally three, are fixed beneath it to receive the different qualities of the washed product.

About twelve or fifteen pounds of the selected stuff from the trunk boxes are placed on the fixed head and washed over the hinge board to the table. It is equally distributed over the board with the aid of a rake or brush, when the water sweeps along the lighter portions, and carries the worthless matter through a

narrow slit at the bottom of the table into a gutter. The selected and rich deposit on the table is washed out into the receptacles beneath it by inclining the latter to one side, and a fresh quantity operated upon

Fig. 601.



as before. The contents of the first, second, and third box are washed again on the rack once, twice, or thrice, as it is deemed necessary, before the product of the first vessel is sent to the tossing tub.

Stream tin is dressed by a similar course of operations as the foregoing, only that the ore is first treated in a large trunking box, where the workmen separate by a rake the larger from the smaller particles of ore. After this, the divisions of ore are submitted to a picking, stamping, and washing operation, mostly like that detailed above. With stream tin these processes serve to produce a very pure ore, devoid of most of its earthy components, and ready for the smelter; but when the tin is found in lodes, associated with copper and iron pyrites, the dressing course with simple washings is insufficient to remove the sulphurous compounds, and with which the ore cannot be smelted.

To remove them, the ore from the tossing tub—the *tin wits*—is conveyed to the burning house, and roasted in reverberatory furnaces, or in a kind of roaster called from its inventor BRUNTON'S calciner. The reverberatories are of the usual form, having a bed about nine feet long, five feet wide in the middle, and four feet at the back part, wherein is situated the working door. The charge, amounting to ten or twelve hundredweight of ore, is let down upon the bed through a hopper in the arch, and when roasted it is drawn out to an arched space beneath the bed by a small aperture inside the working door in the latter. The temperature supplied should not exceed a dull red heat, such as will be capable of dispelling the arsenic and sulphur without fusing the sulphurous compounds. Frequent rabbling of the ore on the bed of the furnace expedites the separation of the sulphur and arsenic; but, under all the attentions given, the time for each charge averages, according to the amount of impurities, from eight to twelve hours. The arsenical and sulphurous vapors pass from the furnace into a wide flue, which is divided into a series of compartments or chambers of varied dimensions, for the purpose of arresting the arsenic, and leading to a low chimney usually erected on some adjoining and commanding eminence.

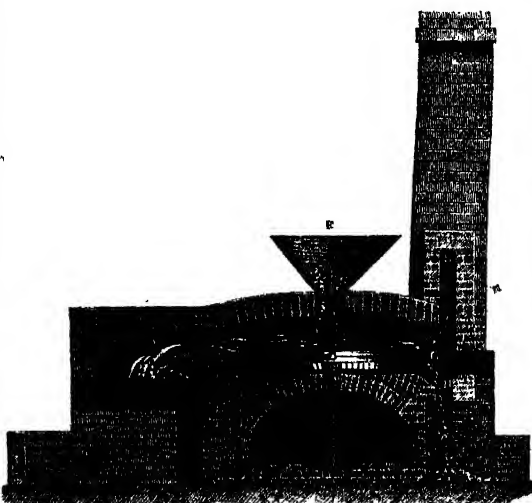
BRUNTON'S calciner is shown in Fig. 602. It is a circular cast-iron table fixed on a stout central shaft,

placed in proper bearings beneath the furnace, so as to permit its turning slowly with the table, C, which is set in motion by a small pinion gearing into a toothed wheel fastened to its under side. This table is fixed beneath the dome of a reverberatory furnace, having a hopper, B, for retaining the ore to be calcined, and in which the upper end of the central shaft turns and distributes the ore on the plate in a continuous stream. The fire is at A, and the products of its combustion pass over the ore to the flue, N, leading to the chimney. Owing to the revolution of the bed of the furnace the ore is kept constantly turned and moved till it travels to the circumference whence it is ejected through the apertures, H, into the receptacle or *wrinkle*, G, in the same ratio that it is supplied from the hopper. Power is communicated to the gearing pinion by a water-wheel or

other means; and the rate at which the ore is to pass over the calciner is regulated by the quick or slow motion of this shaft. Much labor and fuel are said to be economized by the adoption of this system of roasting.

The roasting effects the conversion of the dense metallic sulphides into friable and light oxides, which, being of a less gravity than the tin ore that remains unaltered by the operation, can be readily separated by a proper system of washing. The several kinds of products from the preliminary dressing, such as jigged, fluran, smalls, slime, and roughs, are burned separately,

Fig. 602.



and each subjected afterwards to a particular treatment; thus the jigged parcels are simply jigged again on a copper sieve after the burning; the fluran is passed through the buddle and tie, and the finer divisions are submitted to more complicated processes, consisting of *buddling*, *tossing*, *packing*, and further washing of the residues from these operations on hair sieves, till finally

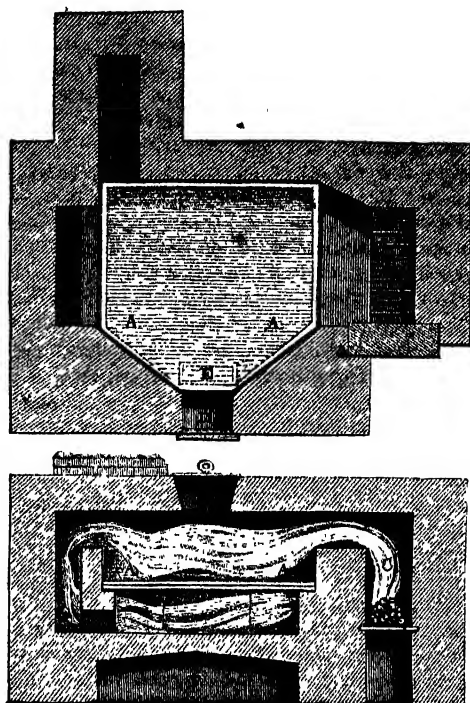
the tin crop remains as pure as possible. Numerous divisions of tin ores are made according to the quantity of the accompanying bodies and their nature, besides those already alluded to; and their dressing gives rise to several refuse matters, the purification of which necessitates a complication of operations, which are varied according to circumstances and the judgment of the superintendent of the mine. The *burned leavings* from the foregoing operations, containing more or less tin, are restamped with some silicious matter and reworked; the crushing with the sand, *et cetera*, detaches from the particles of tin the earthy matters that were combined with them, and that rendered them specifically lighter in the preceding washings. They may now be readily separated by a stream of water in the trunking box or buddle, and the tin obtained.

Improvements in the Dressing of Tin Ore.—Several improved methods of purifying ores of tin have been suggested and practised during the last quarter of a century. The principal of these consist in the use of acids for the separation of the injurious matters from the tin ore, which remains unacted upon by them. By the use of hydrochloric and sulphuric acids the fragments of metallic iron from the tools of the miners, of oxides of iron, copper, *et cetera*, are dissolved and removed from the tin by simple washing, much more effectively, than could be done by any mechanical operation, however carefully performed. Acids have been in use for the dressing of tin ores since 1842, or earlier; muriatic acid being preferred where the impurity is iron and its oxide, and sulphuric acid for the separation of the copper existing in the roasted ore as oxide, which is afterwards thrown down from its solutions by metallic iron or zinc, and the sulphate of iron, or of zinc recovered. LONGMAID'S patent process of separating the sulphur from pyritic ores by fusing them with common salt, whereby the sulphur is converted into sulphate of soda, and the copper into the form of chloride, could be applied to the purification of tin ores containing the foregoing additional metals. Washing the roasted mass would remove the copper salt, and the sesquioxide of iron would be carried off in mechanical suspension, leaving the oxide of tin in a partially pure state behind. The preceding methods of treatment do not serve to purify ores of tin associated with *wolfram*—the double tungstate of iron and manganese—for this mineral has a density averaging 7.1 to 7.4, and therefore so closely approximating to that of tin that no amount of mechanical washing could part the two satisfactorily. Before the process for its purification was discovered, the tin obtained from this kind of ore was very inferior, and consequently the ores themselves were greatly depressed in value. By OXLAND'S method of removing the tungstic acid from them, however, they are so improved that first quality tin can be smelted from them, and necessarily with such purification their value has been correspondingly enhanced. The principle of OXLAND'S patent is that on fusing ores containing tungstates with alkaline salts, such as carbonates or sulphates of soda or potassa, the tungstic acid combines with the alkaline base, producing an alkaline tungstate, which may be dissolved out, and converted to useful purposes in calico-printing or painting, thus

returning as much if not more than the expense involved in the treatment. The tin ore, as finely dressed as possible, is mixed with as much soda ash or crude soda as will be sufficient to form an alkaline tungstate with the amount of tungstic acid which analysis shows the mineral contains. The mixture is then introduced into the bed of a reverberatory, and heated to low redness, which temperature is sufficient to induce the combination of the alkali and the metallic acid body. When the operation is finished, as observed by the color the mass assumes, and the consistency of a thick paste which it takes, it is raked out by an opening in the bed of the furnace into a receptacle beneath, whence it is taken and cast into vats filled with water, which dissolves out the tungstate of soda, leaving the other constituents of the ore untouched. By a judicious use of the water and a properly-constructed vat, the whole of the tungstate can be extracted with very few changes of water, and without diluting the solution to an inordinate degree. While this operation is progressing, the furnace is being charged with a further quantity of the mixture, which is spread out upon the sole, and left so with the furnace doors closed, till the alkali begins to melt and the mass emits a hissing sound, resulting from the expulsion of carbonic acid from the soda salt by the metallic acid. It is then slightly stirred; and when the preceding noise subsides, and the forementioned indications are observed, the roasted mass is ready for drawing. Latterly, instead of carbonate of soda, or crude soda, sulphate of soda or *salt cake* has been substituted, both on account of its cheapness compared with soda ash, and of its answering all the required purposes, in this respect, as well as the latter salt. Some skill and practical judgment are required, however, on the part of the furnaceman who has the control of the process, to insure success. The charge containing a quantity of sulphate corresponding to the tungsten in the ore, is put into the reverberatory—Fig. 603—through the workable opening, *b*, in the arch, and spread by the furnaceman upon the iron bed, *A A*, of the furnace through the working door, *D*. The bed is composed of two stout cast-iron plates fixed in the sides of the furnace, and supported near the centre by lines of brickwork; the space left by this arrangement between the plate and solid brickwork forming a flue for the smoke and waste gases of the fire to return under the sole, and thus assist in heating it. *C* is the fire which at the beginning of the operation should produce a highly carbonaceous flame, with the view of reducing the sulphate of soda to the state of protosulphide, to induce the decomposition of the tungsten and the combination of the acid. For the same purpose some small coal or charcoal is mixed with the charge, the more readily and efficiently to decompose the sulphuric acid of the soda salt. A dull red heat is maintained with all the available openings to the interior of the furnace closed, and a strong reducing flame, till the reduction of the sulphate is effected, occasionally stirring the mixture well till the phosphorescent appearance of the mass disappears. At this stage of the operation a bright oxidizing flame should be produced, to induce the further decomposition of the alkaline sulphide and the

formation of the soluble tungstate; after which it is raked out through the hitherto closed aperture, E, to the vault, F. This process has been carried out at the

Fig. 608.



Drake Wall Mine in Cornwall since 1850 with every success.

The solution of tungstate of soda obtained by the exhaustion of the fluxed ore with water, is concentrated in iron pans to the crystallizing point, and drawn off into crystallizing vessels, where it remains. In a few days the tungstate separates in beautiful crystals, and which, after slight washing and draining, are fit for market. On concentrating the mother liquors a further crop is obtained. After the ore is exhausted of its soluble salts it is transferred to the floor of the burning house, and the iron and manganese separated by washing or treatment with acids, according to the methods already detailed.

From a consideration of the several operations which ores of tin pass through from their coming to *grass*, as it is called, till they are ready for the smelter, it is supposed that fully a third or more of the quantity of tin originally in the ore is lost. Distributed as the tin must be in minute grains in the stony gangue, it is evident that the latter cannot be so thoroughly broken off from the tin as to leave it isolated, and thus in a state to separate in the several washings. Further, where the tin ore is to the whole of the matter mined as one to thirty or thirty-five, a good deal of tin must be rejected in the tailings of the first process which it has to undergo, *videlicet*, the *spalling* and picking;

and analysis of the refuse matters shows that they invariably contain quantities of tin, which loss must be entirely owing to the imperfect, or rather inadequate methods, adopted for disintegrating the ore, and the very slight difference in the low gravity of the gangue which the associated grains of tin ore must occasion, so that such ore will be entirely lost to the miner.

Modern researches show that the loss of tin in the dressing of poor ores is much greater than when richer products are operated upon, in which, however, it amounts to about twenty-five per cent. of the whole quantity. This great loss is attributed to the large amount of tailing stuff produced, and the large body of water made use of in the course of the working. Whilst the existing mode of tin dressing is practised, that loss can hardly be avoided, or at best but slightly lessened. To obtain the whole of the two to three per cent. of binoxide of tin in the tin stuff, the dressing must be based upon chemical rather than mechanical principles. Considering that the loss of tin at present sustained in dressing a hundred tons of stuff averages fully fifty to sixty pounds worth of tin, the recovery of this waste would afford a scope for a partial outlay by which to attain better and more profitable returns.

Many mining companies have of late years substituted crushing mills, such as are sometimes employed in the preparation of copper ores, for the stamping mill, and with great effect and benefit; inasmuch as the crushing mill reduces the ore to a finer state of division, and separates more of the gangue from the hard granules of tin than the stamps, and thereby renders it more easily and freely separable by virtue of its gravity, than when this breaking up is defectively performed. A mistaken notion or prejudice seems to occupy the minds of several miners, with regard to the value of crushers in their line of operations, the more especially if the stuff in which the tin ore is disseminated be indurated slate and the like; for in such cases they seem to be impressed with the idea that the crushers could not work it so well as the stampers. The evidence of many very creditable and experienced persons is directly opposed to this view; and a rational examination of the principles of working with regard to each, would undoubtedly tend to the preference of the crushers. At all events, since the tin miner places so much dependence upon the gravity of the ore as a means by which he can cheaply and expeditiously purify it from grosser and injurious matters, the primary consideration with him ought to be the reduction of the ore to the finest possible state of division. The better this is executed the more completely and expeditiously will the *whole* or chief part of the tin separate in virtue of its density, in a properly ordered system of eluviation.

ASSAYING OF TIN ORES.—Although the laws of the Stannery Court do not permit that the product of the tin mines should be sold out of Cornwall before smelting, it happens that the mining proprietors are never the smelters, and so the ores are sold to a few smelters who have the trade in their hands. These buy as cheaply as they can, and according to the declared value of the ore as ascertained by assay. Hence, as in the case of copper, the ores of tin are always submitted to

this test to find their value, and it becomes a matter of some interest to the miner, as well as the smelter, to be able to control the determinations of recognized assayers, for their own satisfaction and often protection. The operation is very simple, since the dressed ores are generally operated upon, and consequently very little of any other ingredient remains in the substance, excepting the binoxide of tin, and the silicious or other gangue matter, separable by fluxes. Still, as binoxide of tin forms permanent compounds with silicic acid at a high temperature, it is necessary to use some precautions as well in the amount of flux allotted to the assay, as in performing the reduction in a black lead crucible, or an earthen one well lined with charcoal, and at the highest temperature of the wind furnace. If sulphurous or other alterable bodies be present in the ore, these should be removed by roasting a quantity of the ore at a low red heat, and using a little ammoniacal carbonate towards the end of the operation, till nothing further is evolved. The ore should in all cases be reduced to the finest powder; and after the roasting, if the quantity of silica and stony matter be deemed in too great excess, the assay may be carefully washed in a mortar or porcelain dish, and a large quantity of the impure matters thus removed. The heavy deposit of tin ore may then be dried and assayed in the following manner. If the ore be highly dressed, two ounces of it are weighed and mixed intimately with one-third to half this weight of powdered charcoal or coke, and half an ounce of ground borax glass; the whole well ground together, and introduced into a black lead pot, or lined clay one, and this placed on the furnace, the heat of which should be maintained at its highest point for fifteen to twenty minutes. At the end of this period, and when the contents of the crucible are in tranquil fusion, the whole is briskly stirred with an iron rod, and then poured out rapidly into an ingot iron mould. When cold, the slag is detached from the button of tin by a few strokes of the hammer, and by the use of the brush; the button is then weighed. Any matters remaining attached to the walls of the crucible are scraped off and ground, then washed, and the particles of metal that may be thus separated, weighed, and the amount added to that of the principal button. Sometimes the flux is composed of equal parts of borax glass and carbonate of soda, and is found to answer very well; so also is the flux compounded of three parts carbonate of soda and one of lime. Of the former thirty to forty per cent. of the ore taken for assay is employed, and of the latter forty per cent. When ores of tin are very poor, so that they necessitate the use of large quantities of flux, very little tin can be reduced from them, on the scale of assaying, notwithstanding a considerable amount of the metal can be obtained by the treatment of such ores on the large scale. In assaying such ores the better course would be to employ the liquid method of analysis, which will be referred to further on.

SMELTING THE ORE.—Up to the period of the reign of Charles the First, very little improvements are recorded in the smelting of tin. The remains of ancient workings discovered as existing previous to the above period, appear to indicate that the reduction

was carried on in furnaces or hearths scooped out of the ground, and in which a mixture of black tin and charcoal was placed, the necessary intensity of the heat being kept up doubtless by the blast of rude bellows, and the whole operation being similar to the metallurgic process of the travelling tinkers of a few years ago—and perhaps of the present day in Ireland—whereby cast-iron and other refractory metals were readily melted and cast into shapes, such as smoothing irons, *et cetera*. Remains of such furnaces are of frequent occurrence in Cornwall and Devon, and are called *Jew houses*. One of these smelting forges lately discovered beneath a stratum of bog, twelve feet thick, at Redmoor, contained some tin, peat which had been used as fuel, and furnace scoria, with other remains. An analysis of the scoria from other furnaces in the same locality, and apparently of a more modern date than the preceding, showed the imperfections of the methods of smelting. The following are the results which samples presenting the appearance of thin fragments of bottle glass gave:—

	Centesimally
Silica,.....	40.60
Alumina,.....	19.20
Oxide of tin,.....	22.85
Protoxide of iron,.....	7.31
Sulphide of iron,.....	9.04
Lime,.....	trace
Potassa,.....	1.00
	100.00

From the other remains found in the site of the slags, *et cetera*, from which the above was taken, it would appear that the date of working could not have been later than about the year 1630. Attempts were made in the reign of the first CHARLES to employ pit coal instead of peat and charcoal; but the results were unsatisfactory till the first few years of ANNE'S reign, when improved methods of smelting ores of tin in blast furnaces, by means of fossil fuel, were patented by a Mr. LIDDELL. At this period, and when the advantage of fossil fuel above peat and charcoal began to be recognized, the invention of the reverberatory

Fig. 604.

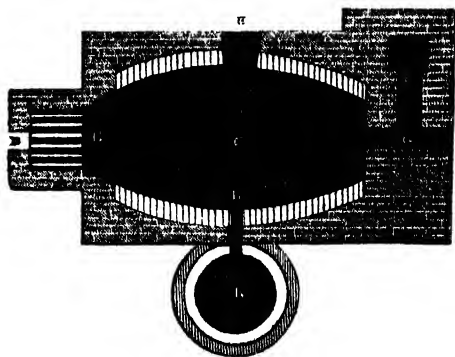


furnace soon followed, in which forms of furnaces tin ores have hitherto, but with slight modifications, been smelted.—*Records of Mining and Metallurgy*.

Figs. 604 and 605 are a plan and section of the smelting furnace at present employed in the smelting of tin ores. In these figures, A is the fire supplied through the door, B; C is the bed of the furnace, constructed of fire-

brick, and supported by the arch, D, having a passage for cold air beneath it, and in the bridge, E, of the furnace, to prevent the overheating of the mass of brickwork in the bed. The charging door is seen at H, and G is the opening through which the charge is worked in the furnace; F is a draught-hole temporarily opened whilst the slags are being skimmed off the metallic bath, and I is the flue leading to the chimney. The ore, which generally averages from sixty to seventy-five per cent. of metal, or, as estimated by the tin assayers and smelters, twelve to fifteen parts, in twenty of ore, is mixed with twelve to eighteen per cent. of powdered anthracite coal, and twenty to twenty-five hundredweight, or a little more, of this mixture, taken for the working charge in the ordinary sized furnace; a small quantity of lime or powdered fluor spar is added in proportion to the amount of silica contained in the material. The whole is shovelled in at the charging door, and spread through this and the working door; after which both doors are closed, and the fire is urged for a period of six to eight hours, gradually increasing in intensity. At the end of this time the ore is well rabbed and mixed by the furnaceman through the hinder door, with the view of bringing the unreduced portions of ore still remaining, within the influence of the heat, and reducing flame from the fire, and the unconsumed carbon of the charge, and likewise of allowing the separated metal to collect into a bath. For a second time the doors are closed, and the interior is allowed to regain its high degree of heat, somewhat reduced during the working of the mass. After a short interval

Fig. 603.



the furnaceman throws some moist slack on the surface of the fused mass in the furnace, and then commences to draw out the top layers of scoria through the working door, to the extent of three-fourths, or thereabouts, of the entire quantity. Whilst this part of the work is being proceeded with, it is customary to open the draught-hole, F, so as to allow the gases to ascend and leave the interior of the furnace partially exposed to the examination of the furnaceman. The above quantity of scoria, if skimmed off with care, contains no metal worth further search, and therefore it is thrown away. The portions which are afterwards drawn out, however, are separated into two classes; the first and largest portion is set aside to be stamped, in order to separate the

globules, or *prills* of metal diffused through it to the amount of five per cent., or nearly so; and the second, or final skimmings from the metal in the furnace, are reserved to be melted with a succeeding charge of metal or refuse products, when not only the particles of metal are recovered, but also the tin in the state of binocide contained in it. When the metallic bath is cleaned in this way, the clay plug hitherto closing the gutter, L, leading to the cast-iron pot, K, is removed, and the tin allowed to flow into the latter. The metal rests here for some time; meanwhile a fresh charge is introduced into the furnace; after which all the apertures are closed as before, and the fire kept up, as already stated. After the metal has remained in the pot sufficiently long to permit the slag and other impurities to rise to the surface, these matters are skimmed off, and the tin is ladled out into cast-iron moulds, each capable of containing about three hundredweight.

The tin so procured always contains a certain amount of impurities, the greater when less care has been exercised in the dressing of the ore. These are generally iron, lead, and some other bodies, according to the nature of the accompanying ore, such as copper, tungsten, arsenic, and cobalt. To separate them, however, it is necessary to submit the crude tin to either of two operations—the one, a process by which the more fusible tin is sweated out at a low temperature, and called *liquation*; the other, a *boiling* or *tossing* of the metal, by which portions of it, by its extended exposure to the air in this operation, are converted into oxide; and being in this state agitated with the body of the metal, the oxygen is transferred to the more oxidizable metals, which are thrown off as a scoria, and can be removed by skimmings.

For the liquation, the smelting reverberatory above described, or one similarly constructed, may be used. The blocks of tin are loosely piled upon the hearth, and a moderate heat is applied; the excess of pure tin melts at the low heat, and flows out by the gutter to the receiver, leaving in the furnace an alloy richer in impurities, and therefore, owing to the more refractory nature of the alloyed metals, requiring a higher temperature for melting it than the purer tin. As the progress of heating crumbles and melts the blocks of tin, fresh ones are supplied till about five or six tons of metal have run out to the cast-iron receiver, wherein the second operation is conducted. This receiver is so arranged as to admit of being heated with the view of aiding in the more ready separation of the contaminating ingredients during the boiling or tossing.

The purification by boiling is analogous in principle to the *poling* practised in refining copper, though differing in detail. In the case of copper, the gases eliminated from the wood—watery vapor principally, and some carbohydrogen—serve to decompose the metallic sulphide left, eliminating the sulphur as sulphurous acid and sulphide of hydrogen; whilst in that of the purification of tin, the metal abstracts oxygen from the steam similarly generated, and the oxide of tin thus partially produced, reacts upon the particles of alloyed metals more oxidizable than itself, and eliminates them as oxide, being itself reconverted to the metallic state.

The method of procedure with tin is to have a bundle of billets of green wood mounted on a crane erected by the furnace, and overhanging the pot containing the melted metal; this bundle is forced into the fluid mass, and the result is a violent scething, caused by the eliminated gases. A scum forms in which oxide of tin is a constituent; this is skimmed off and retained to be remelted with a fresh charge, or with the scoria produced in the first reduction. The action of the wood is renewed, and the scum removed, till by a test applied to the metal it is judged sufficiently purified.

Instead of using wood, the process of *tossing* may be practised with the same effect; that is, the metal is taken up in ladles and allowed to fall from a certain height into the caldron; in this case a scum is formed, and is removed in the same way as stated till the metal is deemed pure. The time occupied in the purification averages about five hours; one hour is devoted to the liquation, three to the boiling or tossing, and one to the subsidence of the metal after it has been thoroughly cleaned by the repeated skimming. During this final hour the metal disposes itself into three qualities of tin: the purer and more fluid metal constitutes the top layer, which is carefully cast or ladled into the moulds, and set aside as grain tin; the middle, which is not so pure, is likewise removed to moulds and retained as common tin; whilst the third portion is returned to the furnace to undergo liquation a second time, to purify it from the greater part of the vitiating ingredients.

The manner of testing the quality of the metal is as follows:—The refiner takes a small ladleful of the melted metal, and having cleaned it by stirring and skimming, casts it into a stone ingot mould, and as it cools, he closely observes its appearance. If it remains bright and clear, full and rounded on the sides, until quite cold, it is sufficiently pure to be classified as grain tin; if the metal, though bright, should not remain so full and rounded at the sides, and if at the moment of solidifying a frosted crystalline appearance shoots from the centre out to the sides, the tin is accounted as second class or common tin; and in the third place, if the metal assumes a slight yellowish appearance, and the crystalline stria appear much sooner, covering the whole of the surface, it is of the third class, and must be repurified by liquation, *et cetera*. The creaking sound emitted by the ingots when bent, is likewise a test which shows the quality of the metal, for this is much greater in proportion to the purity. In tin-smelting works, one day a week is usually devoted to the purification of the crude metal from the reduction of the ore.

The matter remaining in the furnace after the liquation of the tin, is melted at a higher temperature, and run out into another pot, whence it is cast into moulds. This, with the metal washed out from the rich slags after stamping, and the skimmings of scoria, as well as those produced in the refining pot, are remelted, and the metal which results carried through the same course of operations detailed above. Finally, there remains in the pot a bright brittle alloy, having a crystalline fracture and so surcharged with foreign

metals that it is cast aside as not worth the expense and trouble of purification.

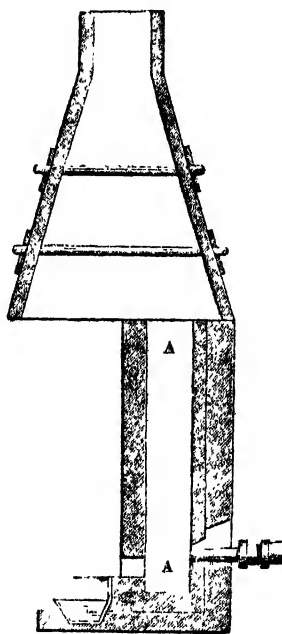
The following is the composition of the three qualities of tin obtained by the preceding operations, according to BERTHIER'S analysis:—

	Centesimally.		
	Ordinary Tin.	Common.	Bad.
Tin,.....	99.76	98.64	95.00
Copper,.....	.24	1.16	3.00
Lead,.....	—	.20	1.50
Iron,.....	trace	trace	—
Arsenic,.....	trace	trace	trace
Loss,.....	—	—	.50
	100.00	100.00	100.00

The consumption of fuel for producing one ton of tin is reckoned in the Cornish smelting works at a little more than a ton and a half, sometimes thirty-five hundredweight, and the loss of tin in the process amounts to about five per cent.

German Method.—In the tin-smelting establishments of Altenberg, *et cetera*, instead of the reverberatory, a

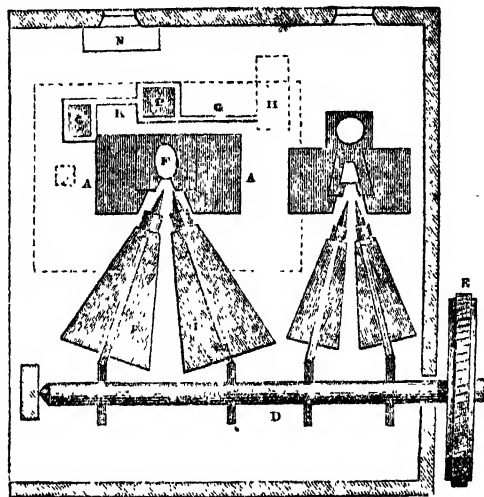
Fig. 606.



small blast furnace is used for the reduction of the ore. Figs. 606 and 607 are a plan and elevated section of this furnace; its height from the hearth to the throat, by which the mixture of ore and fuel is inserted, is fourteen feet. The body, A A, is constructed of large blocks of granite or of coarse-grained porphyritic syenite, and the sole or crucible is formed of a block of the same material hewn to the proper shape, with a fall to the breast of the furnace; but sometimes it is constructed of very refractory fire-bricks, lined with a mixture of charcoal and fire-clay well rammed down. A channel from the furnace leads into a basin, B, from which the slags flow down an incline, C, to the water

cistern, H, where they are cooled, and the tin by another conduit, K, flows into the vessel, C. The blast is supplied by the bellows, I I, through the tuyere opening, O. The furnace is surmounted by a dome which serves to carry off the vapors, and as a depositing

Fig. 607.



chamber for the particles of ore driven out of the furnace by the blast. The shaft, D, is turned by the cog-wheel, E, in connection with a shaft from a water-wheel or steam-engine. The small furnace, the parts of which are similar to the preceding, is employed for remelting the slags produced from the larger furnace. The furnaces are slowly dried after their construction, and then charged with scoria and fuel, and the blast slowly set to work, so as to fuse the more vitrifiable portion, after which the heat is increased till the temperature is raised to the working intensity. The ore, mixed with the reducing agent, and other flux, when necessary, is now charged portionwise, and the smelting proceeded with. At the end of four hours the metal begins to flow. As the slags collect in the basin at the face of the furnace, they are skimmed into the water cistern, and when the metal accumulates so as to nearly fill the basin, it is allowed to flow into the outer one, C, whence it is cast into moulds of varied dimensions. Much of the same practical knowledge is required in the management of this furnace; as has been pointed out under the smelting of copper ores in the blast furnace; for the length of the nozzle formed of the slags, on the end of the tuyere affects the working, and the charge must be regulated accordingly.

It is affirmed that the tin reduced in the blast furnace is purer than that smelted in the reverberatory; but the loss of metal and the consumption of fuel is much greater; and these disadvantages have led to the abandonment of the blast furnace in England for the reduction of tin. Smelting by the use of the blast involves a loss of metal averaging fifteen per

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cent., and a consumption of fuel amounting to three tons of coal for every ton of metal reduced.

Tin is sent to market as *block tin*, in blocks of three to half a hundredweight, and which are cast, as stated in the foregoing, in strips two feet long, one inch wide, and half an inch thick, being so cast in moulds of white marble; and in the form of *grain tin*; the last being produced by heating large blocks of the metal to nearly its melting point, and while in this state, dropping it upon a hard body from an eminence, or striking it with a heavy hammer—in either case, the mass is shattered into long crystalline fibrous columns.

USES OF TIN.—The principal uses of tin are for the manufacture of various alloys which are largely used in the arts, such as bronze, bell-metal, solder, *et cetera*; for making *tin plates*, or rather iron plates, alloyed with the metal; and for preparing tinfoil, whilst its compounds are employed for pottery, in glazes, and colors; and in cloth-printing, as mordants of great value and importance. The reader will find the account of bronze under COPPER, Vol. I., page 534; and of solder, usually compounded of two parts of lead and one of tin. Tin-foil is manufactured similarly to lead-foil, by passing slabs of it backwards and forwards under a pair of rollers; the temperature of the metal being raised occasionally, or maintained throughout, at 212°. The production of tin plates is one of the principal, if not the principal application of tin, and as such this manufacture will be described more in detail.

MANUFACTURE OF TIN PLATES OR SHEET-TIN.—

As the superior quality of tin plates depends almost entirely upon the goodness of the iron which constitutes their basis, and the care taken in its preparation, it will be necessary, from the importance of the subject, to dwell at some length upon this part of the process.

The pig-iron selected for the manufacture is generally that known as *red short*; but other varieties may be used, the iron being converted during the purification into plates, the essential qualities of which are great tenacity and toughness at ordinary temperatures. Iron from hematitic ores mixed with other pure ores of the coal measures, answers all the required ends. It has an average composition corresponding with the following samples, containing centesimally:—

	I.	II.	III.	IV.	V.	VI.	VII.
Carbon.....	3.47	3.70	2.37	3.42	4.23	3.27	—
Silicium....	1.40	1.33	0.81	1.63	0.49	1.03	1.55
Sulphur....	0.10	0.02	0.54	0.15	0.37	0.04	0.05
Phosphorus	0.60	0.12	0.26	trace.	0.36	0.38	0.18
Iron.....	94.43	94.93	96.02	94.80	94.55	95.28	—
	100.00	100.00	100.00	100.00	100.00	100.00	—

Tin plates are divided into two classes, and known by the terms *charcoal* and *coke* plates, owing, in the first place, to the nature of the fuel used in the preparation of the plates before tinning; but, more particularly at present, these names serve to distinguish the goods manufactured by entirely different methods. Charcoal tin plates were the first that were made, and they have been accounted the best. The iron for these plates is rendered tenacious and workable by the aid of a charcoal refinery through which the pig-iron, is passed; and that for the *coke* tin plates is prepared by the

G T

ordinary method of puddling and rolling, as described under the article IRON. It will, therefore, be unnecessary to revert to the latter; and so far as the mere coating of the prepared plates is concerned, the description to be given will answer for both. To convert the iron into charcoal tin plates, it is necessary to refine it in a shallow furnace called a *refinery*, the sides and bottom of which are formed of hollow, but very massive blocks of iron, through which a stream of water is kept continually flowing, to protect them from the intense heat of the melted charge. This furnace is of a rectangular shape being four feet long, two and a half wide, and one and a half deep. On one side are three tuyeres for the admission of blast; and these are sometimes round, sometimes oval, the transverse diameters of each in the latter case being 1·15 inch, and its conjugate one inch; they are placed about a foot from the bottom of, and project considerably into the furnace, inclining downwards at a sharp angle. These, like the block forming the furnace, being subjected to a powerful heat, are protected by a coil of iron pipe, twisted round them, through which pipe a stream of cold water is kept always passing. Occasionally, refiners are constructed of larger dimensions than that described, having tuyeres at both sides; these are usually called *double refiners*. A coke fire is made in the space between the *water-blocks* or hearth, and the blast turned on till the whole is thoroughly ignited; a fresh supply of fuel sufficient to fill the space to the height of three feet above the tuyeres, is then heaped on; and, after a few minutes' blowing to increase the heat, a charge of pig iron, varying according to the size of the furnace, and generally reduced for the first time, is put on; the coke is soon ignited, and the metal attains a red heat quickly, after which, the heat being still kept up with fresh supplies of fuel, the metal gradually sinks, and as it comes into contact with the blast, it melts and drops to the bottom of the hearth. The downward direction of the tuyeres causes the stream of air to impinge on the highly-heated liquid iron, and thereby renders the temperature of the latter intense, owing to a portion of the metal being oxidized, as well as the silicium, sulphur, *et cetera*. All these products of oxidation are thrown up to the surface, and form a considerable amount of scoria or cinder that considerably aids in the depuration of the metal. Generally, in an hour and a half after charging, the furnace is fit for tapping; the metal is run out into iron moulds prepared for it, and which are protected against melting by a stream of cold water that flows beneath them. These moulds are sometimes flat, in which case the metal is called *plate metal*. In South Wales, however, it is more usual to run the liquid iron into moulds, consisting of three longitudinal grooves or channels,

having raised dams or *stops* at the distance of every five feet, to facilitate the breaking of the metal. As it runs out of the refinery, it is covered by minute, intensely brilliant, and very numerous coruscations arising from the combustion of a portion of the fluid; these coruscations are accompanied by a brown smoke—a phenomenon also of the BESSEMER process. As the metal runs out, the slag or cinder, which is likewise highly heated, flows after it, forming a layer on the surface of the moulds, and thus prevents further combustion of the iron. Cold water is now thrown on the whole, when the cinder at once froths up and solidifies on the surface, causing it to assume a spongy appearance that distinguishes it from all other kinds of slag formed in the several processes for refining iron. The first charge worked in the refiner is less than the following ones; but the normal weight, about twenty-two hundred-weight, is attained after the third. The number of charges worked every twenty-four hours is eleven or twelve; and the weight of refined metal produced in a week of six days and five nights averages sixty tons, for which about seventy-two tons of pig are required. The produce varies, however, according to the skill of the refiner, the quality of the material used, and the nature of the required product.

Good refined metal has a bright silvery-white fracture, and a radiated structure, the rays springing and diverging from the lower side; it emits a clear metallic sound when struck, is very brittle, with its upper surface indented into a kind of honey-combed structure, the depth of the indentations being dependent on the length of time that the iron has been subjected to the blast. About half an inch deep of honey-comb is considered to indicate the state of refinement best suited for the making of tin plates. It is somewhat curious that, as the refined metal graduates into steel, the honey-comb leaves the face or upper side, and tends to the centre of the horizontally-cast ingot.

The effect of the refining, as before stated, is the removal of the silicium, and of a portion of the sulphur and phosphorus contained in the crude material. The silicium is converted by oxidation into silicic acid, which combines with a portion of the iron oxidized, and forms a fusible slag or cinder on the surface of the metallic bath. The sulphur is converted into sulphurous acid gas, and passes off as such, and the phosphorus into phosphoric acid, which is retained in combination with the oxide of iron in the slag. Very little of the carbon, contrary though it be to the preconceived opinion of iron-masters, is removed during the preceding course of refining, as is sufficiently proved by analysis, and will be evident from an examination of the annexed table showing the composition of different specimens of refined iron:—

	I.	II.	III.	IV.	V.
Carbon.....	2·070	3·250	2·000	3·200	—
Silicium.....	·630	·500	·540	·550	0·32
Sulphur.....	·157	·575	1·250	0·870	0·18
Phosphorus.....	·734	·835	·085	·920	·09
Manganese.....	trace	—	·056	trace	·24
Insoluble residue.....	·530	·050	—	—	—
Iron.....	95·140	96·300	94·255	95·000	—
	100·261	101·510	99·046	100·540	—

Although the above samples were not made from the cast-irons, the analyses of which have been previously given, yet they serve to prove what has been just stated regarding the chemical changes that take place in the fire. By comparing the results of the two series of analyses, it will be found that only one-seventh of the carbon is separated at the same time that one-half of the silicium is removed. On the other hand the sulphur and phosphorus are in larger quantities in the samples of refined than in the crude metal, showing at least that very little if any of these elements are separated, or else that the crude material submitted to the process was of very bad quality. It appears, however, that fully one-third of the content of phosphorus and somewhat more than this amount of the sulphur, with nearly the entire silicium in the pig, are thrown off, the carbon suffering only a slight diminution.

The following analysis shows the nature of the refining cinder thrown off during the operation:—

Silica	23.76
Protoxide of iron	61.28
Oxide of manganese	3.58
Alumina	7.30
Lime	2.41
Magnesia	0.76
Sulphur	0.46
Loss	0.45
	100.00

Besides the foregoing method of refining, two others, long followed to some extent, are known—the first is a modification of BESSEMER'S process, and the second is one patented by Mr. PARRY of the Ebbe Vale Iron Works. In the first, the action of the blast is stopped when the melted iron has passed to the state of refined metal; but as the iron prepared in this way has never been used in the manufacture of tin plates, it will be needless to prolong the description. The metal purified from common Welsh pig contains centesimally—

Sulphur	1.040
Phosphorus	1.128
Silicium	trace

PARRY'S process differs considerably from those referred to. According to it the melted pig-iron is run at once from the blast into a reverberatory furnace very similar to that used in puddling. On each side of this are three or four small tuyeres pointing downwards to the hearth, through which superheated steam is forced at high pressure; they are so arranged that the current will cause a gyration of the surface of the metal, and thereby expose fresh surfaces of it continually to the blast. The action produced is similar to that effected in the ordinary refinery—the oxygen of the steam, together with that passing over the grate, causes the necessary oxidation, and, therefore, the formation of cinder as before. It should be observed that in this process a considerable quantity of rich cinder, such as hammer slags, mill-scales, *et cetera*, is added to the melted metal in the refinery, and the result of the union is that much of the iron in those cinders is reduced and converted into refined metal, so that in most cases the product equals the amount of metal introduced from the melting furnace. This

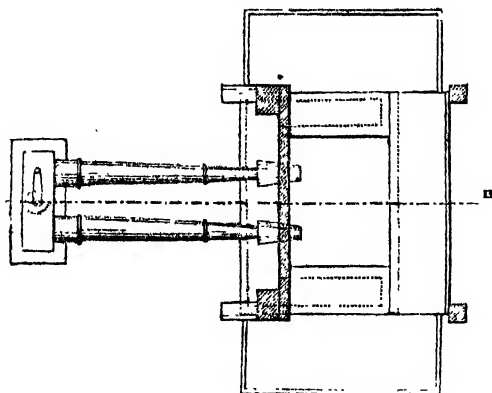
result is brought about by the carbon in the molten mass acting upon the rich slag, and reducing the iron in it to the metallic state simultaneously with its own consequent conversion into carbonic oxide, in which form it escapes; hence the cinder produced, though abundant, contains less iron than that formed under ordinary circumstances, namely, only thirty per cent. The hydrogen, likewise, has an important effect; it acts upon the sulphur and phosphorus of the metal, and converts these into sulphide and phosphide of hydrogen, which, like the carbonic oxide just mentioned, escape. The metal is thus rendered much purer, and well adapted for the manufacture of tin plates.

The next operation is the refining in the charcoal fire, in a furnace similar to the old blooming fire used in this country previous to the introduction of the puddling process. It consists of a shallow hearth eighteen inches deep, twenty-eight by thirty-two inches at the upper part, and twenty by twenty-one inches at the lower. On one side is placed a Δ -shaped tuyere protected, like the others spoken of, seven or eight inches from the bottom. The tuyere side and that opposite to it are occasionally constructed of *water blocks*, but generally of dry iron plates. Charcoal is the fuel used, and, in recently-constructed works, the products of combustion pass through a chamber at the back of the fire, and there raise the charge of metal to a red heat previous to its introduction into the fire. The refined metal being thus heated, it is drawn down into the fire, the whole of the hearth of which has been previously filled with charcoal, so as to completely cover the tuyere; more fuel is then added, and the blast turned on. In twelve to fifteen minutes the metal begins to melt, and at the end of forty-five minutes it is completely molten and lies on the bottom just under the blast. The workman now proceeds with a bar to break it up and raise it into more immediate contact with the blast, exposing it by this operation on all sides. A small quantity of cinder is thus formed, after which it is tapped off and another charge of heated metal let down and treated in the same way till the whole coheres into one mass. This occurs about an hour after charging. At this period it is usual in most tin works to add a bundle of shavings, cut from the edges of the *black plate* presently to be described. This new addition is very quickly blended with the previously formed *loops* of iron; so that in about ten minutes after adding it, the whole will be in one mass at the bottom of, and nearly filling, the hearth. During this part of the work very little fuel is required, merely sufficient to cover the iron. It is now taken out of the fire and freed from scurf and cinder as much as possible, all the pieces thus separated and the scales from the *helve* being taken back to the fire for the next charge. The loop is first hammered into a roughly cylindrical bloom and then into a flat irregular shape of about two inches thick. In this plate are cut deep grooves parallel with one another, and six inches apart. It is then thrown into cold water to cool, and broken into the rectangular pieces previously roughly indicated by the parallel grooves or notches. The charge of refined metal taken in this operation is about two hundred and seventy pounds, and the loss is such that to make one ton of

charcoal-refined, or stamped iron, as it is sometimes called, requires twenty-two hundreds of refined metal and about eight bags—equal to one hundred and twenty cubic feet—of charcoal. The number of charges worked off in the twenty-four hours averages eighteen.

The effect of this process is to continue, and, in a

Fig. 608.

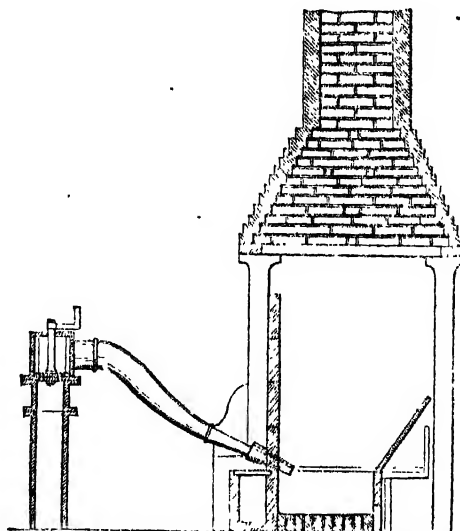


in which it breaks under the hammer. In fact this is almost the most important operation in the whole series which constitute in the aggregate the manufacture of tin plates; and if it be not properly conducted all subsequent treatment results in loss and vexation. The chemical reactions that are effected are a continuation of the carbon in the iron, and the separation of the sulphur and phosphorus, with other impurities, by the same agency. The similarity between the two methods now treated of and the BESSEMER process must be apparent to every one; the only difference being the presence of carbon in both, the plans described, to prevent the excessive oxidation and loss resulting from the patented method of BESSEMER.

In some works it is usual to run the fluid metal direct to the charcoal fire, and this practice certainly economizes fuel, as all the caloric absorbed in raising the refined metal from its cold state to the melting point must be saved. When this is the case, the refinery is made very much smaller than that before mentioned, and is charged with only six hundredweight of pig, which, when refined, supplies two charcoal fires. This kind of furnace is often called a *running out* or *dandy fire*—Figs. 608 and 609, the former a plan and the latter a vertical section on the line A B of the plan—and is now very generally used. Instead of using charcoal in these fires, it is customary in some localities to use a very light, spongy coke, and this difference gave rise to the terms *coke* and *charcoal* plates, though at present the former name is applied to puddled iron. Coke of this nature has received great attention recently; and there can scarcely be a

great measure to complete, the purification begun in the previously described process, the result being, in fact, crude wrought-iron. The fresh fracture presents very large, bright, and flattish crystals, of a silvery color; and its fitness for the subsequent processes is mainly judged of by its appearance, and by the manner

Fig. 609.



doubt of the fact that if this fuel is carefully manufactured from a proper and pure coal, and finished by the action of steam while hot, according to a process lately patented by Mr. R. S. ROPER, it forms as good a fuel as charcoal; and that tin plates made in this way are not to be distinguished in appearance or quality from the charcoal plates.

The charcoal iron next undergoes a reheating and welding process. One of the rough irregularly oblong pieces, weighing about thirty pounds, is laid on a flat plate of iron with a long handle, called the *portal* or *staff*, and placed in the *hollow fire*—shown in elevation in Figs. 610 and 611—where it is raised to a soft welding heat previous to reducing it to blooms. Fine sand is thrown on the surface of the metal from time to time, to remove the oxide or *scale* formed on it by the action of the heat and the free oxygen entering the fire, which scale, if left on it, would interfere with the proper welding. Afterwards it is carried to the hammer and beaten into a bloom, as stated above, and welded to the portal; this is again returned to the hollow fire, three other pieces of the charcoal iron being previously placed upon it, and after its temperature is raised as before, again worked into a bloom six inches wide and two thick under the hammer. This is cut nearly in the middle, and the parts doubled up on one another—reheated—rehammered into a bloom six inches by four—then taken to the hollow fire to be reheated—cut off from the portal—and finally passed several times through a series of grooves in a pair of rollers till it is reduced to a bar or slab six inches wide and half an inch thick. These dimensions,

however, vary slightly particularly the thickness, according to the size and gauge of the plates afterwards to be rolled from them.

The *hollow fire* alluded to is one of the earliest applications of the gas flame to metallurgical purposes, having been in use upwards of seventy years, previous to which an earlier form, was used, and is still employed in the charcoal forges of North Lancashire; in this early form the iron was surrounded by a dome

apertures for the entrance of air are allowed to exist. To remedy the evil many experiments have been made to avoid this process altogether, but hitherto without leading to the adoption of any advantageous plan. Mr. WILLIAM DANIEL patented a mode of dispensing with the operation, but it is only partially carried out, though it was in a great measure successful. He directs to put the lump from the charcoal refinery under the hammer, where it is *nobbled* or hammered into a roughly cylindrical bloom, then passed through the rolls and reduced to a bar six inches square and about two feet and a half long. This bar is then either cut or sawn into pieces six inches long, and rolled endwise to give a bar six inches wide, two and a half thick, and twelve long; afterwards this billet is heated in a small balling furnace, and rolled down to a bar a quarter of an inch thick, eleven wide, and about six feet long. This is at once taken to the tin plate mill and made into plates.

It is necessary to revert here to the *coke tin plates*, which name, as already stated, was originally applied to them in consequence of the kind of fuel used in the second refining operation. At present it means those produced from puddled iron rolled into bars similar to those described in the preceding, and called *tin-plate bars* or *tin bars*. In all the subsequent processes the same *modus operandi* is followed, whether the tin bars be made from the puddled or from the hollow fire iron—charcoal tin bars; therefore the following description of the process to which the bars are subjected, previous to, and up to their conversion into tin plates, applies equally to both kinds.

The bars are taken to the shears, where they are cut to proper lengths in accordance with the size of plates to be made—thus for No. 1 c plate, which is $13\frac{1}{2} \times 18$

—see table, page 1071, the length of piece will be fifteen inches, the exact dimensions of it being $15 \times 6 \times \frac{3}{8}$ inches. These short pieces are then placed in packs in a reheating furnace, having a very slow draught, and there raised to a dull red heat; they are next passed singly breadthwise several times through a pair of narrow flat rolls; reheated, and then drawn out across the original fire to a length of five feet and a half. Such plates are then doubled down, and the ragged ends produced in the rolling shaved off. After this they are returned to the furnace and heated to redness, passed through a pair of rollers similar to the last, but more carefully turned to give them a very smooth surface, and there rolled till each is drawn out to five feet—this virtually being two plates five feet long united at one end. The combined plates are again doubled, the waste end sheared off, returned to the fire, and when heated repressed under the rolls till they are extended to about forty-three inches, the entire forming four plates. The operation of doubling, heating, and rolling, is continued sometimes till the original plate is reduced to eight and even sixteen

Fig. 610.

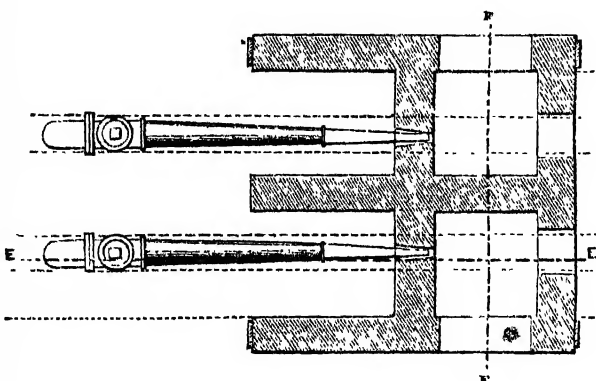
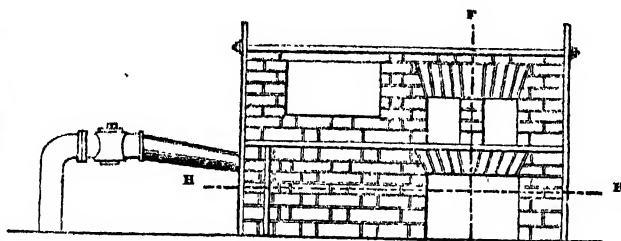


Fig 611.

of ignited fuel, the flame from the combustion of which produced the necessary heat. In the present modification, the furnace is of bricks, and in three divisions—at one end is a space containing ignited coke, into which a continued blast of air is blown by two tuyeres; the flame thus produced passes into the middle position, where the iron to be heated is placed; and the third or middle-end division is intended for the partial heating of said iron by the waste heat, preparatory to its being introduced to the middle division.

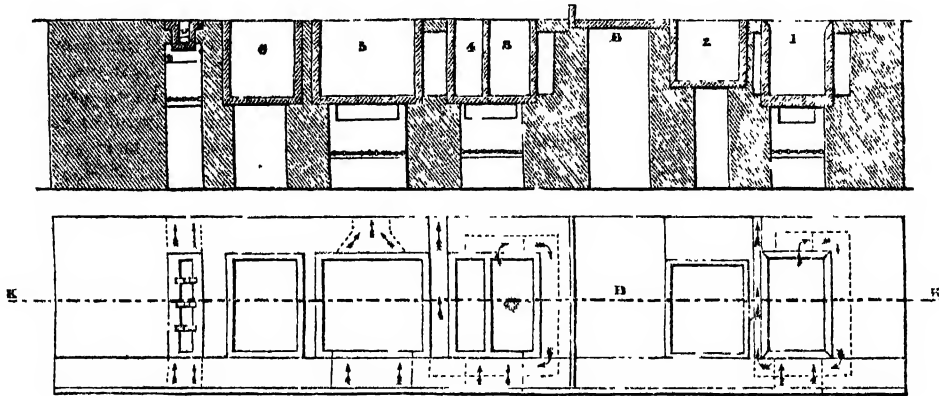
The operation just described is a most wasteful one, involving a loss of three or four hundredweight of iron per ton of bars made; and this is the more striking as the material operated on is wrought-iron. It is owing chiefly to the numerous heatings to which the metal is submitted, and the large volumes of oxygen that enter the furnace through its numerous openings, and possibly also the excess of blast blown into the coke. The latter cause of loss might be avoided by care on the part of the workmen; but it is to be feared that the waste can be but slightly diminished while so many

plates, all passing under the rollers as one. It is to be observed, that great care is required to prevent the plates from being welded either by a too high heat, or from a neglect of partially separating them from time to time, by the rollers. In this way the original piece of bar is rolled into four sheets, each forty-three inches long by fifteen wide. The plate of four, eight, sixteen, or thirty-two thicknesses, or sheets, is then taken, unopened, to a pair of shears, which cut off the two ragged longitudinal edges at one stroke, and at such distances as to determine the length of the tin plates; they are then cut across by the same machine at distances equal to the intended breadth of the same; and thus are obtained four, eight, sixteen, or thirty-two plates in each division of the proper dimensions, still so closely pressed as apparently to be but one. They are next separated, and all the defective ones picked out; such, for instance, as contain streaks of dirt pressed into them, those welded together, and the like, and the choice ones, called in this state *black* plates, are taken to the *pickling* room. Here they are immersed in a bath of warm dilute oil of vitriol during fifteen or twenty minutes, to remove the scale of oxide

on them. The acid leaves them with a clean dullish-grey metallic surface; and to assist the action of the acid in this respect the plates are rubbed with sand and water, and afterwards washed, when they are ready to be sent to the *annealing* house.

It will be readily understood that, after the repeated rollings and the immense strain the plates have been subjected to, they are at this stage very brittle; and therefore, if turned in this state, they would not bear to be hammered into the multitudinous and complex shapes required in commerce. To remove this defect, the process of annealing is had recourse to, and the work is conducted thus:—The plates are placed to the number of about eighteen hundred—for common sizes—in piles, within a cast-iron box about two feet square, the lid carefully luted on to prevent air entering, and then placed with several similarly filled ones in a stove constructed very much in the shape of a reverberatory furnace, but considerably larger, and having its bed on a level with the ground. The fire-bridge being tolerably high, the flame from the grate rolls slowly over the boxes, and raises them gradually to a cherry-red heat, at which temperature they are main-

Fig 612.



tained during twelve hours, and then withdrawn. When quite cold, the covers are taken off, the plates taken out, carefully examined, and sorted. If the heat has been too high, some of the plates will be found adhering to one another; if too mild, they will not be much improved by the operation, and if air should have entered, they will be either partially or completely converted into scale or oxide of iron. After being subjected to this process, the plates will have a deep plum-color bloom on their surfaces, due to a very thin film or coating of oxide that has formed upon them. They are now passed three times through a pair of rolls similar in form to those previously described, but with which great pains have been taken, to make their surface hard, smooth, and brilliantly polished. Then rolls are placed in close proximity, so that the plates passing between them are subjected to a very great pressure, but not sufficient to enlarge them. After having been thus *cold rolled*, as it is termed, the plates are extremely smooth, and possessed of a lustrous and dappled appearance, still owing to

the thin oxidation. One effect of this rolling is to make the plates brittle once more, and therefore to necessitate a second annealing, which is performed in the same way as the preceding; but the heat is milder, and the time reduced to five or six hours. Another sorting follows, when the good plates are sent to the *tin house*, and the defective ones returned with the shearings of the *black* plates to the *charcoal fire*.

In the tin house the plates are again *pickled* in a warm but more dilute bath of oil of vitriol than that already used, during ten minutes, then removed and well rubbed with sand and water, to detach all dirt and scale. They should now have a smooth, perfectly clean, greyish metallic surface, in which state they can be kept in cold water without injury for some time, and are ready for the *tinning*.

TINNING.—The apparatus or *stow*—Fig. 612—for this process consists of a series of baths set side by side, for the convenience of the workmen, each bath having a fire beneath it, to keep the materials they severally contain in a fluid state. These baths

or pots are six in number—namely, 1, the tinman's pot; 2, the tin-pot; 3, the washing or dipping pot; 4, the grease-pot; 5, the cold-pot; and 6, the list-pot. The tinman's pot is full of melted grease, and into this the plates are immersed and left till all moisture upon them is evaporated, and they become completely covered with the grease. It is about two feet long, fifteen inches wide, and twenty inches deep. From the tinman's pot the plates are removed to the tin-pot, and plunged into the bath of melted tin, protected with a layer of grease which it contains, and remain in it for about twenty minutes. This pot has a capacity of $22 \times 18 \times 16$ inches. In the first dipping the alloy is imperfect, and the surface not uniformly coated, consequently the plates are removed to the dipping or wash pot, which is divided into two compartments. The first immersion takes place in the larger division, which contains molten tin covered with grease like the last, and here the plate is left sufficiently long to make the alloy complete, and to separate any superfluous tin which might have adhered to the surface. The workman then takes out each plate separately to a table between the wash-pot and the grease-pot, and wipes it on each side with a brush of hemp to remove any excess of tin; to obliterate the marks of the brush, he dips it quickly into the second compartment of the wash-pot, and then at once into the grease-pot. This second compartment of the wash-pot always contains the purest tin; and as it becomes alloyed with iron, it is removed to the first compartment of the same, and thence to the tin-pot. The grease-pot is filled with melted grease; and great care is necessary to maintain it at the proper temperature. Its purposes are to allow any superfluous tin to run off, and especially to prevent the alloy on the surface of the plate cooling more rapidly than the iron. If this were neglected, its surface would be cracked. After ten minutes' immersion in the grease-pot the plate is removed to the cold-pot, which is filled with tallow heated to a comparatively low temperature. The pots 4 and 5 serve the purpose of annealing the plates, and of cooling them down

to a low temperature. The last one in the series is the list-pot, and is a small cast-iron bath kept at a sufficiently high temperature, its bottom covered with tin to the depth of a quarter of an inch. In this the edges of the plates are dipped and left in till the wire of tin, which usually forms on them in the course of the foregoing processes, melts, and is removed by a quick blow on the plate with a stick.

The articles are now tin plates; but before they are sent to market, they undergo some further treatment. Firstly, they are carefully rubbed with bran to clean them from grease and dirt; secondly, they receive another rubbing with a pad of sheep-skin, retaining its wool; and thirdly, they are sent to the sorter, whose duty it is to pick out defective plates, and to arrange the good ones in piles according to their size and quality. They are finally packed in boxes, which are branded on the outside with the marks indicating the size and quality of the plates, and sent to market.

Quality of Tin Plates.—The tests for tin plates are ductility, strength, and color; and to possess these, the iron used must be of the best quality, and all the process be conducted with care and skill. The following conditions are inserted in some specifications, and will serve to indicate the strength and ductility of first-class tin plates:—

1st, They must bear cutting into strips of a width equal to ten times the thickness of the plate, both with and across the fibre, without splitting; the strips must bear, while hot, being bent upon a mould to a sweep equal to four times the width of the strip.

2nd, While cold, the plates must bear bending in a heading machine, in such a manner as to form a cylinder, the diameter of which shall at most be equal to sixty times the thickness of the plate. In these tests, the plate must show neither flaw nor crack of any kind.

The following table exhibits the usual brands and their value in dimensions of plate, number, and weight per box, and may be found useful for reference:—

TABLE OF MARKS, WEIGHTS, AND DIMENSIONS OF TIN PLATES.

Name.	Size inches by inches.	Number in box.	Weight of box. cwt. qr. lbs.	Mark or brand.
Common, No. 1,.....	$13\frac{1}{2} \times 10$	225	1 0 0	I C
" No. 2,.....	$13\frac{1}{2} \times 9\frac{1}{2}$	"	0 3 21	II C
" No. 3,.....	$12\frac{1}{2} \times 9\frac{1}{2}$	"	0 3 16	III C
No. 1, cross,.....	$13\frac{1}{2} \times 10$	"	1 1 0	I X
No. 1, 2 ".....	"	"	1 1 21	I X X
No. 1, 3 ".....	"	"	1 2 14	I X X X
No. 1, 4 ".....	"	"	1 3 7	I X X X X
Common doubles,.....	$16\frac{1}{2} \times 12\frac{1}{2}$	100	0 8 21	C D
Cross doubles,.....	"	"	1 0 14	X D
2 cross doubles,.....	"	"	1 1 7	X X D
3 ".....	"	"	1 2 0	X X X D
4 ".....	"	"	1 2 21	X X X X D
Common small doubles,.....	15×11	200	1 2 0	C S D
Cross ".....	"	"	1 2 21	X S D
2 cross ".....	"	"	1 3 14	X X S D
3 ".....	"	"	2 0 7	X X X S D
4 ".....	"	"	2 1 0	X X X X S D
Wasters, common No. 1,.....	$13\frac{1}{2} \times 10$	225	1 0 0	I C W
" cross No. 1,.....	"	"	1 1 0	I X W
" common small doubles,.....	15×11	200	1 2 0	C S D W
" common doubles,.....	$16\frac{1}{2} \times 12\frac{1}{2}$	100	0 3 21	C H W
" cross doubles,.....	"	"	1 0 14	X H W

The Editor thankfully acknowledges his obligations to his late talented pupil, Mr. R. S. ROPER, for his assistance in preparing the preceding remarks on tin plates.

ULTRAMARINE.—*Outremer*, French; *Lazurstein*, German.—This is one of the most beautiful pigments known, and its artificial production is justly viewed as belonging to the greatest triumphs of modern chemistry. It is obtained by isolating the coloring matter of lapis-lazuli, outremer, or lazurstein, mostly brought from China, Thibet, and the shores of Lake Baikal. It is a mineral of indeterminate composition, as will be seen from the annexed analyses—

	Gmelin.	Dann.
Silicic acid,	49.00	45.50
Sulphuric acid,	2.00	5.90
Alumina,	11.00	31.80
Soda,	8.00	9.10
Lime,	16.00	3.50
Magnesia,	2.00	—
Sesquioxide of iron,	4.00	0.80
Sulphur,	trace	—
Water,	trace	—
Chlorine,	—	0.40
Loss,	8.00	2.00
	100.00	100.00

Lazulite often contains scales of mica and iron pyrites. It is found in masses, more or less pure, generally in small volume, fragile, but capable of scratching glass, of granular texture, imperfectly laminated, and almost transparent at its edges. It crystallizes in dodecahedrons, with rhombic faces, but the crystals are rare—specific gravity, 2.50 to 2.96. The hue, which occurs in isolated places, merges from celestial to pure blue and indigo purple. It is usually disseminated in a rock, which contains many other laminated substances, among which is a fine white lazulite. In the *Musée Mineralogique* at Paris are two fine specimens of lazulite, in which is seen the transition from the azure to the white. TOMLINSON remarks that the iron pyrites sometimes propagated in lazulite, is of a bright yellow hue, helping to relieve the lustre of the blue, and they have often been mistaken for pellets of gold; in fact, the cause of its intense blue color was long a matter of controversy. No traces could be detected of cobalt, copper, or any other element or compound known to impart an azure tint. The existence of an unknown protoxide of aluminium— AlO —was even assumed as a means of solving the difficulty; and not until ultramarine had been prepared artificially, and the synthetic proof had thus been superadded to the analytical, was it admitted that a blue tint could be produced by the union of three colorless bodies—*alumina, sulphur, and soda*.

CLÉMENT and DÉSORMES published an analysis of this substance in 1806; they admit, of course, the great difficulty experienced in analyzing ultramarine. They regarded it to have the following composition, which is in many respects similar to the results obtained by WILKENS, and subsequently given—

	Centesimally.
Silica,	35.80
Alumina,	34.80
Soda,	43.20
Sulphur,	8.10
Carbonate of lime,	3.10
	100.00

The great cost of ultramarine, and the unparalleled effects which it produces in painting, rendered it most

desirable to produce this compound artificially. Chemists were for some time baffled by the discordant results each obtained, and were thereby unable to distinguish which of the ingredients of ultramarine were essential, and which accidental or superfluous.

The first step, says TOMLINSON, towards the production of this pigment artificially was in 1814. VAUQUELIN, in visiting the plate-glass works at St. Gobain, was informed by the director of the sulphuric acid and soda department of the establishment, that, in taking down the soda furnaces a blue mass was found when *grès—gritstone*—was employed in the formation of the sole, but there was no such deposit when the sole was of brick. The Editor has often remarked in black-ash furnaces the production of ultramarine; in fact, all recent analyses of this substance give about one per cent. of this blue pigment. VAUQUELIN took some of the compound, reduced it to powder, and, washing it, found it was decolored by the mineral acids, with the disengagement of sulphide of hydrogen; that it was not attacked by boiling alkaline solutions, nor destroyed at a red heat. This chemist further states, that though the composition of this artificial product is unlike that of lapis-lazuli, yet he is not without a hope that the circumstance may lead to the production of ultramarine artificially. This observation, and the suggestion founded upon it, appears to have been forgotten for nearly fourteen years. To Gmelin of Tübingen the honor of the discovery of artificial ultramarine is generally said to be due; but, as TOMLINSON remarks, if the question of priority were raised, then it must be claimed by the *Société d'Encouragement* of Paris, who offered a prize of six thousand francs for the manufacture of ultramarine. GUIMER obtained the prize in 1828, on which occasion he communicated his recipe confidentially to GAY-LUSSAC.

To prepare the pigment lapis-lazuli, freed from all mechanical impurities, is gently ignited, slaked in water, and reduced to an extremely fine powder. This is now incorporated with a melted paste called *pastelle*, consisting of linseed oil, wax, and resin, and kneaded under cold water. Ultramarine gradually deposits in the vessel as a dark-blue powder, which grows brighter by degrees, whilst the impurities remain entangled in the *pastelle*.

The color thus obtained is of necessity very expensive, from the rarity of the material, and from the tedious and wasteful mode of producing it.

The preparation of artificial ultramarine has undergone many modifications since the experiments of Gmelin. BRUNNER mixes seventy parts of silica, two hundred and forty of burnt alum, forty-eight of charcoal powder, one hundred and forty-four of flowers of sulphur, and two hundred and forty of anhydrous carbonate of soda, all reduced to an impalpable powder; puts the mixture in a Hessian crucible, and lutes down the cover. The crucible is heated to moderate redness, and kept steadily at that temperature for an hour and a half, and then suffered to cool. If the operation has succeeded, the mass has a loose, half-fused appearance, and a greenish or reddish-yellow hue. If solid, fused, and brownish, the heat has been too high. The mass is taken out of the crucible, and washed till the liquid has no longer a sulphurous taste. The residue, a dark

greenish-blue powder, is filtered, dried, mixed with its own weight of sulphur, and one and a half times its weight of anhydrous carbonate of soda, and heated as before. The residue is boiled with water for some time, filtered, and washed till the liquid no longer blackens carbonate of lead. The dried powder is sifted, and submitted to the following final process:—A plate of cast-iron is covered to about the depth of a line with pure sulphur, upon which the compound is sifted to about an equal depth. The plate is then cautiously heated till the sulphur takes fire. The residue is removed from the plate, again pulverized, and resubmitted to the same treatment with sulphur, until the color is found satisfactory.

BRUCKNER adopts a somewhat modified process. Sulphide of sodium is prepared by igniting sulphate of soda with charcoal powder. This is dissolved in water, some free sulphur is added, the liquid is concentrated, mixed with one half per cent. of sulphate of iron and twenty-five per cent. of a well-tempered clay—the purer and whiter the better—the mixture evaporated to dryness, the residue powdered, and ignited for an hour in a cupelling furnace; when cold, it is extracted with water, the residue dried, powdered, and once more heated in a muffle, when the required tint appears.

A still further simplification is to ignite sulphate of soda with charcoal powder and clay in a crucible, with slight access of air.

TIREMON's recipe for this pigment is the following:—One thousand and seventy-five parts of crystallized carbonate of soda are fused in their own water of crystallization, and the fused mass mixed by stirring, first with five parts of red sulphide of arsenic, then with a quantity of hydrate of alumina, prepared from alum by precipitation with carbonate of soda, and containing seven parts of anhydrous alumina, and lastly, with a mixture of one hundred parts of sifted clay, and two hundred and twenty-one parts of flowers of sulphur. The mass, after being intimately mixed and evaporated to dryness, is introduced into a crucible provided with a good cover, and gently heated at first, in order to expel the remaining traces of moisture, the temperature being afterwards raised to full redness. The mass should cake together without fusing. If the materials have not been properly mixed, the whole will exhibit white spots; and if it has been fused, it is studded with brown ones. After cooling it is roasted, in order to expel the greater portion of the sulphur, then reduced to powder, and washed slightly on a filter with cold water. The bluish-green powder thus obtained is again roasted for an hour or two, with occasional stirring, in covered basins, at a temperature never exceeding low redness. According to ELSNER, a very small quantity of iron, such as is usually contained in the ingredients, is essential to the production of the hue, but excess is injurious. A mixture of one part of clay, perfectly free from iron, with one part of sulphur and two parts of anhydrous carbonate of soda, yields a yellowish mass when ignited; but if a trace of sulphate of iron is added to the mixture, a mass is obtained which is black, green, or blue, according to the degree of heat to which it has been subjected. When potassa is used instead of soda, GÜELIN states the blue tint is not obtained.

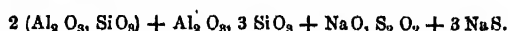
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Before the analysis by MARGRAF, the color of ultramarine had been attributed to the presence of copper, but this chemist only found sulphuric acid, lime, and iron; others suspected, naturally enough, the presence of cobalt; others again, hydrofluoric acid. KLAPROTH's results indicated the following:—

Carbonate of lime,	28.00
Sulphate of lime,	6.50
Alumina,	14.50
Silica,	46.00
Sesquioxide of iron,	3.00
Water,	2.00
	100.00

GUYTON thought that the coloring matter was a blue sulphide of iron.

Pure ultramarine, according to WILKENS, has the composition—



It should contain, therefore, theoretically—

	Per cent
Silica,	38.75
Alumina,	26.37
Sulphur,	13.68
Soda,	21.20
	100.00

an assumption which agrees pretty closely with the actual analysis of the purest samples. A variety of substances, such as iron, lime, potassa, magnesia, sulphuric acid, and chlorine, may be present as impurities, and were, in part at least, purposely added by the earlier manufacturers; but they are found to be perfectly unnecessary. The coloring matter appears to consist of hyposulphite of soda and sulphide of sodium. If the firing be conducted in porous crucibles, the coloration of the mass is generally unequal.

GREEN ULTRAMARINE.—Ordinary ultramarine, on ignition with saltpetre, assumes a green color. Green portions, more or less in quantity, are frequently formed in the crucibles, especially on the first ignition. On repeated heating it passes into a blue tint. Artificial ultramarine is, however, very rarely entirely freed from all traces of the green modification, and hence it is, for the most part, less beautiful than the natural variety.

Ultramarine is readily decomposed by acids, with evolution of sulphide of hydrogen, and total destruction of the color. At a high temperature this effect is even produced by silica, whence the unfitness of ultramarine for painting on glass and porcelain. Solutions of potassa and soda have no decomposing action, even at a boiling temperature. By a prolonged red heat ultramarine is rendered perfectly white, and then no longer evolves sulphide of hydrogen on the addition of an acid.

Tests.—Purchasers frequently judge of the comparative value of samples of ultramarine by mere inspection—a most fallacious method. The eye may indeed decide on the purity of the blue, but it can give very little notion of its depth. In other words, it is impossible to determine, by mere inspection, how far a sample has been let down with some colorless substance. It is better to take equal weights of the respective samples under examination, and to grind up each with

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ten to twenty times its weight of gypsum. When thus let down, a difference in the depth of color becomes perceptible.

BERNHEIM prepares a normal solution by mixing one ounce of concentrated sulphuric acid with twenty grains of water; equal weights—fifty to one hundred grains—if the various samples to be examined are next taken, and each placed in a separate glass. The normal liquor is now added from a graduated burette until the blue color is converted into a reddish one, and no blue particles are perceptible. The quantity of sulphuric acid consumed in each case shows the relative value of the sample. If cobalt is present, the blue color of the sample cannot be completely destroyed by the acid.

Uses.—Ultramarine is employed as a pigment by artists and decorators. Under certain circumstances, however, it gradually loses its color if ground with oil. It is also used in printing cotton and woollen goods, being fixed to the fibre either by solutions of albumen and casein, or by shell-lac varnishes. It is abundantly employed as a *powder-blue*, in getting up white cotton and linen goods. For this purpose it is ground up with soda-ash, chalk, gypsum, or any other cheap white matter, and sold sometimes under its own name, but more frequently as superfine Saxon smalts. This fraud is much in vogue in a sea-port town on the Eastern coast of England notorious for its manufacture of inferior and spurious colors. The detection is not difficult, since hydrochloric acid at once destroys the color of ultramarine, whilst it is without action upon genuine smalts.

VARNISH.—*Vernis*, French; *Firniss*, German.—In the commonest acceptation of the term, a varnish consists of a resin of some description dissolved in a fluid more or less volatile, which, on evaporation, leaves the resin in the form of a lustrous film. It is generally applied by means of a brush in successive coats, and is laid on in the direction of the fibres of the wood. The most desirable feature of a good varnish is durability, dependent upon the quality of the resin and its solvent.

The principal substances employed in making varnishes are the following:—

SOLVENTS.

Oil of nuts—alcohol.
Oil of linseed—ether.
Oil of turpentine—wood-spirit, pyroxilic alcohol, or hydrated oxide of methyle.
Oil of rosemary—methylated spirit.

SOLIDS.

Amber,	Colophony,	Elemi,
Anime,	Copal,	Lac,
Benzoin,	Damara,	Mastic,
	Nandarac.	

COLORS.

Aloes,	Dragon's blood,	Red saunders,
Annotto,	Gamboge,	Saffron,
Cochineal,	Indigo,	Turmeric.

The spirituous varnishes dry most rapidly; this advantage is, however, partly counterbalanced by their aptitude to crack and to peel off. This defect is partially remedied in the turpentine varnishes which dry more slowly. But in those called *oil-varnishes*, this defect is alone entirely obviated: in these a small quan-

tity of a drying oil is added to the solution of the resin in rectified spirit of turpentine; and although they take a longer time to dry, they are all the more durable.

Before treating of the various varnishes, a description will be given of the chief resins before mentioned, as being employed in the manufacture:—

Amber is most distinguished for durability. It is usually of some shade of yellow, transparent, hard, and moderately tough. Heated in air it fuses at about 549°; it burns with a clear flame, emitting a pleasant odor. When pounded, absolute alcohol extracts succinic acid and resin; the latter to the extent of about one-eighth of the weight of the amber. In fact, amber is a mixture of several resins. It resists the action of solvents so greatly, that it requires to be fused and kept in a state of fusion—for oxidation—at a somewhat high temperature before it is fitted for making amber-varnish. The costliness of amber, as well as the length of time it takes to dry, are the chief objections to it.

Anime is imported from the East Indies. The large, transparent, pale-yellow pieces, with vitreous fracture, are best suited for varnish. Inferior qualities are employed for manufacturing gold-size or japan-black. Although superior to amber in its capacity for drying, and equal in hardness, varnish made from anime deepens in color on exposure to air, and is very liable to crack. It is, however, much used for mixing with copal varnish.

Benzoin is a gum-resin but little used in varnishes on account of its costliness. The finer sorts are brittle, pulverulent, with conchoidal fracture; they fuse at a gentle heat.

Colophony is synonymous with arcanson and rosin. When the resinous juice of *Pinus sylvestris* and other varieties is distilled, colophony remains in the retort. Its dark color is due to the action of the fire. Dissolved in linseed oil or in turpentine by the aid of heat, colophony forms a brilliant, hard, but brittle varnish.

Copal is a gum-resin of immense importance to the varnish-maker. It consists of several minor resins of different degrees of solubility. In durability it is only second to amber; when made into varnish, the better sorts become lighter in color by exposure to air.

Copal is generally imported in large lumps about the size of potatoes. The clearest and palest are selected for what is called *body-gum*; the second best forms *carriage-gum*; whilst the residue, freed from the many impurities with which it is associated, constitutes *worst quality*, fitted only for japan-black or gold-size.

Copal is tasteless and inodorous; transparent and of conchoidal fracture. Heat softens it without rendering it viscid. In alcohol it is but little soluble; but it is said to become more so by reducing it to a fine powder, and exposing it to atmospheric influences for twelve months. Boiling alcohol or spirit of turpentine, when poured upon fused copal, accomplishes its complete solution, provided the solvent be not added in too large proportions at a time. The addition of camphor also promotes the solubility of copal; so likewise does oil of rosemary.

Dammara is a tasteless, inodorous, whitish resin, easily soluble in oils. It is not so hard as mastic, with which it forms a good admixture.

Elemi is a resin of a yellow color, semi-transparent,

and of faint fragrance. Of the two resins which it contains, one is crystallizable and soluble in cold alcohol.

Lac constitutes the basis of spirit-varnish. The resin is soluble in strong alcohol aided by heat. Its solution in ammonia may be used as a varnish, when the articles coated with it are not exposed more than an hour or two at a time to water.

Mastic is a soft resin of considerable lustre. The two sorts in commerce are, in *tears* and the *common mastic*; the former is the purer of the two. It consists of two resins—one of which is soluble in dilute alcohol. With oil of turpentine it forms a very pale varnish of great lustre, which flows readily and works easily. Moreover, it can be readily removed by friction with the hand; hence its use for delicate work of every description.

Sandarac is a pale odorous resin, less hard than lac with which it is often associated as a spirit-varnish. It consists of three resins differing as to solubility in alcohol, ether, and turpentine. It forms a good pale varnish for light-colored woods; when required to be polished, Venice turpentine is added to give it body.

Of the solvents of these various resins little need be said. In the manufacture of varnishes great care, as well as cleanliness, are required. The resins should be washed in hot water, to free them from particles of dust and dirt; they should be dried and assorted according to their color, reserving the lightest shades for the best kinds of varnish.

The *linseed-oil* should be as pale-colored, and as well clarified as possible. New oil always contains mucilage, and more or less of foreign matters; as these prevent the regular absorption of oxygen, the oil requires preliminary treatment. The common plan is to boil it with litharge; but such *oil varnish* is inferior to that prepared with sulphate of lead.

The best method is to rub up linseed-oil with dry sulphate of lead in sufficient quantity to form a milky mixture. After a week's exposure to the light and frequent shaking, the mucus deposits with the sulphate of lead, and leaves the oil perfectly clear. The precipitated slime forms a compact membrane over the lead, hardening to such an extent that the clarified oil may be readily poured off.

Turpentine is of very extensive use. The older it is, the more ozonized, the better it is. Turpentine varnishes dry much more readily than oil varnishes, are of a lighter color, more flexible and cheap. They are, however, neither so tough nor so durable.

Alcohol is employed as the solvent of sandarac and of lac. The stronger, *ceteris paribus*, the better.

Naphtha and *methylated spirit of wine* are used for the cheaper varnishes. Their smell is disagreeable. The former is, however, a better solvent of resins than alcohol.

SPIRIT VARNISHES.—Mix—

Alcohol	500 parts.
Ether	60 "

Heat in a flask, and suspend therein from a bag, one hundred and twenty parts of finely-divided well oxidized copal. Continue the heat until complete solution takes place.

Such a varnish combines brilliancy and transparency with considerable hardness and solidity. As color is easily generated over the fire, the materials are best digested in a water bath. Such a varnish is, however, only suitable for fancy articles, and is, after all, not equal to a mixture of resins.

A VARNISH FOR PAPER, MATS, ET CETERA.

	Parts
Spirit of wine,	32
Mastic,	6
Sandarac,	3
Venice turpentine,	3
Pounded glass,	4

Mix the pounded mastic, sandarac, and glass thoroughly together, and place them in a tinned copper digester. Add the alcohol, stir well and frequently with a wooden spatula, and heat for several hours in a water bath. When the solution is complete, add the turpentine, stir frequently, continuing the heat for an hour, and strain when cold through a cloth.

This method is applicable to all spirit varnishes.

A WHITE SPIRIT VARNISH FOR VIOLINS.

Spirit of wine,	One gallon.
Mastic,	Two pounds.
Turpentine varnish,	One pint.

A VARNISH FOR WHITE WOODS.

Bleached shellac,	Three pounds.
Spirit of wine,	Two and a half gallons.

The shellac should be first dissolved in a gallon of the spirit, and the rest added after straining.

ANOTHER VARNISH FOR MUSICAL INSTRUMENTS.

	Parts
Spirit of wine,	32
Sandarac,	4
Pounded glass,	4
Seedlac,	2
Mastic in tears,	2
Venice turpentine,	2
Elemi,	1

These varnishes may be readily colored—*red*, by dragon's blood; *yellow*, by gamboge. If a colored varnish is required, clearly no account need be taken of the color of the resins. Lac varnish may be bleached by Mr. LEMMING's process:—Dissolve five ounces of shellac in a quart of spirit of wine; boil for a few minutes with ten ounces of well-burnt and recently-heated animal charcoal, when a small quantity of the solution should be drawn off and filtered: if not colorless, a little more charcoal should be added. When all tinge is removed, press the liquor through silk, as linen absorbs more varnish; and afterwards filter it through fine blotting-paper. Dr. HARE proceeds as follows:—Dissolve in an iron kettle about one part of pearlash in about eight parts of water, add one part of shell or seed lac, and heat the whole to ebullition. When the lac is dissolved, cool the solution, and impregnate it with chlorine gas till the lac is all precipitated. The precipitate is white, but the color deepens by washing and consolidation. Dissolved in alcohol, lac bleached by this process yields a varnish which is as free from color as any copal varnish.

One word in conclusion with reference to all spirit varnishes. A damp atmosphere is sufficient to occasion a milky deposit of resin, owing to the diluted spirit

depositing a portion : in such case the varnish is said to be *chilled*.

ESSENCE VARNISHES.—They do not differ essentially in their manufacture from spirit varnishes. The polish produced by them is more durable, although they take a longer time to dry.

Table Varnish may be made as follows :—

Damma resin,	1 pound
Spirits of turpentine,	2 pounds
Camphor,	200 grains

Digest the mixture for twenty-four hours. The decanted portion is fit for immediate use.

COMMON TABLE VARNISH.

Oil of turpentine,	1 pound
Bees' wax,	2 ounces
Colophony,	1 drachm

COPAL VARNISH FOR INSIDE WORK.

Pounded and oxidized copal,	24 parts
Spirit of turpentine,	40 "
Camphor,	1 "

FLEXIBLE COPAL VARNISH.

Copal in powder,	16 parts
Camphor,	2 "
Oil of lavender,	90 "

Dissolve the camphor in the oil, heat the latter, and stir in the copal in successive portions until complete solution takes place. Thin with sufficient turpentine to make it of proper consistency.

OIL VARNISHES.—These, the most durable and lustrous of varnishes, are composed of a mixture of resin, oil, and spirit of turpentine. The oils most frequently employed are linseed and walnut; the resins chiefly copal and amber, but also the others already recorded.

The drying power of the oil having been increased by litharge, red-lead, or by sulphate of lead, and a judicious selection of copal having been made, it is necessary, according to BOOTH, to bear in mind the following precautions before proceeding to the manufacture of varnish :—1. That oil varnish is not a solution, but an intimate mixture of resin in boiled oil and spirit of turpentine. 2. That the resin must be completely fused previous to the addition of the boiled or prepared oil. 3. That the oil must be heated from 250° to 300°. 4. That the spirit of turpentine must be added gradually and in a thin stream, while the mixture of oil and resin is still hot. 5. That the varnish be made in dry weather, otherwise moisture is absorbed, and its transparency and drying quality impaired.

The heating vessel must be of copper, with a rivetted and not a soldered bottom. To promote the admixture of the copal with the *hot* oil, the copal—carefully selected and of nearly uniform fusibility—is *separately* heated with continuous stirring over a charcoal fire. Good management is required to prevent the copal from burning or becoming even high colored. When completely fused, the heated oil should be gradually poured in with constant stirring. The *exact* amount of oil required must be determined by experiment. If a drop upon a plate, on cooling, assumes such a consistency as to be penetrated by the nail without crack-

ing, the mixture is complete; but if it cracks, more oil must be added.

The spirit of turpentine *previously heated* is added in a thin stream to the former mixture, care being taken to keep up the heat of all the parts. With proper attention to these directions, the following prescriptions from DUMAS, TOMLINSON, BOOTH, and others, will be found of use :—

COPAL VARNISH FOR FINE PAINTINGS.

Gum copal, fused,	8 pounds
Linseed oil, heated to 250°,	2 gallons

Boil for about a quarter of an hour, until the mixture strings strongly, and then add spirit of turpentine, hot, three gallons. Although much loss of turpentine ensues, the varnish will be so much the more transparent, durable, and drying.

CABINET VARNISH.

Copal, fused,	14 pounds
Linseed oil, hot,	1 gallon
Turpentine, hot,	3 gallons

Properly boiled, such a varnish will dry in ten minutes.

BEST BODY COPAL VARNISH.

Copal, fused,	8 pounds
Linseed oil, hot,	2 gallons
Turpentine, hot,	3½ "

The mixture must be slowly boiled for five hours until quite stringy, and subsequently mixed with the heated turpentine. This varnish is well suited for all objects intended for polishing.

In preparing *artists' copal varnish* it is advisable to separate the particles of copal by means of pounded glass, to prevent the gum from adhering, so that a moderate fire will suffice. The older the turpentine the more drying the varnish. Take—

Finest picked copal,	3 pounds
Pounded glass,	2 "
Linseed oil,	3 quarts
Spirit of turpentine,	5 "

All the before-mentioned varnishes are recommended to be made with clarified, but not otherwise prepared oils. Consequently they take long to dry, and cannot be polished for months. Anime is often introduced to hasten the hardening of the varnish, in the proportion of one part to two of copal. But such varnish is less durable. A yet inferior copal varnish contains anime in the proportion of two parts to one of the former.

WATNSCOT VARNISH FOR HOUSE PAINTING AND JAPANING.

Anime,	8 pounds
Clarified linseed oil,	3 gallons
Litharge,	½ pound
Acetate of lead,	½ pound
Sulphate of copper,	½ pound

All these materials must be carefully but thoroughly boiled together until the mixture becomes quite stringy, and then five and a half gallons of heated turpentine stirred in.

Such a varnish is, of course, every way inferior to one made with a carefully prepared drying oil, as above prepared by the aid of sulphate of lead. But it exsiccates very rapidly, and is well suited to the common purposes

for which it is intended. It can be easily deepened in color by the addition of a little gold-size.

The varnish used in India for palanquins is made by melting a kind of sandarac, and mixing it with boiling and drying linseed oil. Mr. RHODE, in *Balfour's Cyclopædia*, knows of no better or more durable polish for teak and chittagong wood particularly, than may be prepared by melting three or four bits of sandarac, of the size of a walnut or small egg, and pouring upon it a bottle of boiling linseed oil previously rendered drying by boiling litharge or other dryer, and after boiling them together gently for an hour, adding while cooling a teaspoonful of venice turpentine. If too thick, it may be thinned with spirit of turpentine. It should be rubbed on the furniture, and after a little time—during which it may be exposed to the sun—rubbed off. The friction should be continued daily, and the polish should not be again applied for eight or ten days; after which it may be slightly applied every one or two months. Water does not injure this polish, and any stain or scratch may be rubbed over, which cannot be done with French polish. To give the appearance of gold to silver leaf used by the Condapilly Moochies, for ornamenting boxes, palanquins, *et cetera*, a little aloes is dissolved in the varnish, which is laid over it. A very good varnish is prepared by Moochies with shell-lac and wood oil, heated in small quantities.

French polish is employed upon flat surfaces, and consists simply of a solution of resin in spirit of wine. The simplest sort of French polish may be made by dissolving one and a half parts of shell-lac in eight parts of spirit of wine. Such a polish is very durable, but many other gum-resins are employed. A good dark-colored polish is prepared from one pound of shell-lac, half a pound of gum-benzoin, and one gallon of spirit of wine. Others recommend twelve ounces of shell-lac, three ounces of copal, six ounces of gum-arabic, to one gallon of spirit.

The *lacker* used for wood work or brass is also a varnish. For brass the proportions are half a pound of pale shell-lac to one gallon of spirit of wine. It is better prepared without the aid of heat, by simple and repeated agitation. It should then be left to clear itself, and separated from the thicker portions and from all impurities by decantation. As it darkens on exposure to light, the latter should be excluded. A pale yellow lacker may be made by mixing one ounce of gamboge, and two ounces of Cape aloes, with one pound of shell-lac. For a bright yellow half a pound of turmeric and two ounces of gamboge are required; for a red lacker, half a pound of dragon's blood and one pound of annatto. It need scarcely be said that the color will also be modified by that of the lac employed.

WATER.—*Eau*, French; *Wasser*, German; *Aqua*, Latin.—The poet SOUTHEY thus appositely writes of this all-important fluid:—

Most blessed water! neither tongue can tell
The blessedness thereof; no heart can think,
Save only those to whom it has been given
To taste of that divinest gift of heaven.

In the very first record of that fiat of the Creator, which called forth by omnipotent volition the innumerable planetary bodies distributed in infinite space, the primary matter especially mentioned is water: *And the Spirit of God moved upon the face of the waters.* Whether the circumstances of the creation, as related in Genesis, differ from the order observed in giving form to, and producing diversity of, objects upon the earth by the great First Cause, is a question which does not affect one way or another, the subject of the present article; although the study of the disposition of the principal objects within the limited range of man's sphere of inquiry, geographically and geologically considered, demonstrates most conclusively, that water has fulfilled functions in the formation of mineralized and other strata in the solid crust of the earth, of undeniable importance. It is not previous to the generation of vegetal and animal life, however, that the importance of water, as an abundant and primary constituent of the globe, can be properly estimated; for it is only in the fulfilment of the higher designs of Providence, such, for instance, as the production and sustenance of vegetal and animal life and organization, that any approach to an adequate notion of the great ends which water serves, can be formed. Without water no organized structure, whether of vegetal or animal, could, in the human estimation of things, preserve its functions and reproduce itself in obedience to the great generic law of Nature. Independently of its essential importance in this respect, water serves another purpose only secondary to it—namely, that of distributing a medium temperature over the whole surface of the earth, conformably to certain physical laws which will be subsequently alluded to, thereby insuring a genial warmth which is absolutely necessary for the development of plants and animals. It may be assumed, that for some such or other similar all-wise dispensations, the extent and quantity of water on the globe greatly surpasses that of the land. It is well known that water is capable of combining with caloric to a great degree; and, owing to the superficies of the globe being to the extent of two-thirds, water, it is evident the chief portion of the heat derived from the sun is stored in this liquid, for the purpose merely of being eliminated gradually to compensate the earth for that which, owing to its superior radiating power, it gives off so freely as to chill it to a degree prejudicial to organized life, unless supplied by winds or air-currents, passing over the surface of large tracts of waters. This capacity of storing caloric possessed by water is subservient in other respects, not only for equalizing the heat of the habitable portions of the globe, but for the distribution of the liquid itself over the arid parts of the earth. For instance, the warm rays of the sun would be unendurable in the torrid zone, were it not that in these regions large quantities of water are evaporated, and that every unit of it thus converted into vapor renders latent or insensible above one thousand units of heat, thus beautifully neutralizing the violent effect of the sun's intense rays. Again, the aeriform moisture ascends obedient to its expansive force, and diverges laterally to colder regions, where the water having parted with a great portion of its acquired temperature, condenses into clouds, and finally falls as rain, hail, or snow, to refresh and nourish life in its multifarious varieties;

whilst a current of air from colder regions loaded with water rushes to the locality whence it was driven, to compensate the loss of moisture, and maintain the equilibrium of temperature. Thus is a beautiful provision for the preservation of organic life and the maintenance of a genial warmth sustained, a provision which, from its regularity and precision, is called a physical law, though in reality a divine and beneficent dispensation.

Water is therefore of primary importance as well in the physiology as in the economy of life, and quite as indispensable as the air breathed from the dawn to the close of man's existence; without them all other provisions of nature would, under existing circumstances, be inadequate to sustain vitality.

HISTORY.—In considering water scientifically, it offers a wide and an interesting field of inquiry to the aspiring student. For a long time many earnest minds were misled regarding its nature, nor was it till almost within the span of the present age—namely, in 1781—that its true composition was revealed. Formerly, philosophers, universally following the footsteps of the ancients, regarded it as one of their elements, though, in later times, some among them were found who considered it transmutable into an earth by repeated distillations, in consequence, as LAVOISIER subsequently proved, of the glass vessels in which the operations were performed, undergoing slight disintegration on the surface, and giving rise to a crust of silicious and other matters contained in the glass. Its real nature lay hidden and subject to conflicting hypotheses till, by the superior powers of deduction, aided by a deep and patient penetration into the secrets of phenomena, according to the principles of chemistry as then understood, CAVENDISH, by most conclusive and beautiful researches, as well synthetically as analytically, revealed its true nature as a compound body. Like all other inventions and discoveries of great importance, there were others ready to claim the honor, such as WATT and LAVOISIER; but evidently the principles which they enunciated appear to have originated with CAVENDISH, and had been communicated through PRIESTLEY and others to the forementioned philosophers, previous to the publication of the account of CAVENDISH's researches on the subject. The light thus shed upon the knowledge of chemical phenomena, might appropriately be placed in juxtaposition with the brilliant lustre emanating from the discovery of oxygen by a PRIESTLEY, or from that of the atomic theory by a HIGGINS and a DALTON. The phenomena attending the combustion or explosion of hydrogen gas in common air, and the endeavors of WARLTHIRE to deduce from the experiment whether or not caloric was ponderable, seem to be the primary facts that led subsequently to the discovery of the composition of water. PRIESTLEY, WARLTHIRE, and doubtless others, too, repeated the experiment frequently; and although water was a product in every instance, yet no one before CAVENDISH seems to have given the necessary attention to the question of how this water was formed. After numerous trials regarding the proportions of air and hydrogen that were required to produce this important liquid, CAVENDISH found these to be two volumes of hydrogen and five

of air. Subsequently the research in this direction recommended itself to other philosophers, among whom GAY-LUSSAC fixed the respective quantities of the component gases necessary to produce water at one volume of oxygen and two of hydrogen.

PREPARATION.—When two volumes of hydrogen and one of oxygen gas are mixed in a confined vessel and ignited by means of the electric spark, a slight flash of light and loud explosion follow their combination, and water remains in the vessel to the extent of the weight of the combined gases. In like manner, when hydrogen issuing from a small jet is ignited, and a deep cylindrical glass is inverted on the flame, water is produced; and, owing to it being condensed on the cold surface of the glass, appears first as a slight coating of dew, and subsequently in the form of small drops which trickle down the walls of the vessel. Many other means are now known, whereby pure water from its elements is produced, such, for instance, as transmitting pure hydrogen gas over several metallic oxides inclosed in tubes, and heated to redness. The most conclusive experiment for demonstrating the composition of water is that performed by the aid of the galvanic battery. In this experiment, the constituent gases are evolved at the respective poles of the battery in the ratio of two volumes of hydrogen and one of oxygen; and by mixing these gases in a eudiometer or other tube, and transmitting the electric spark through them, water is again reproduced. It would be tedious to specify the numerous ways in which water can be formed from the combustion of hydrogen. It may be instanced, however, that finely-divided platinum—platinum black—possesses the power of causing the combination of the gaseous constituents of water in a remarkable manner. The principle of DOBEREINER's instantaneous light is founded on this same property.

The arrangement by which the decomposition of water may be illustrated, consists simply of a glass globe with stopper openings at the sides and at the top, filled with water. Small platinum wires pass through the corks at the sides, and up through the apertures at the top, terminating in flat plates of the same metal. Two graduated tubes filled with water are inverted over these plates, and the zinc and copper poles of a voltaic battery connected with the protruding wires at the side, thus converting the two tubes into ordinary decomposing cells. On setting the battery in action, the water in the tubes will undergo decomposition in part, oxygen being formed on the side of the copper or positive pole, and hydrogen on that of the zinc or negative pole; both gases, as they accumulate, ascend to the closed ends of the tubes, forcing out the water. By reading the index on the tubes, it will be found that the quantity of hydrogen in the tube inverted on the zinc pole will be strictly double the volume of the oxygen in the other; in other words, the elements are evolved in the exact ratio of their existence in water, as may be proved experimentally by exploding the mixture of both gases in a cylinder over mercury.

PROPERTIES OF WATER.—Water, like gases and elastic bodies generally, possesses very varied properties both of a physical and a chemical nature. The knowledge of the former constitutes the chief division

of two correlative branches of the physical sciences, namely, hydrostatics and hydrodynamics; the former relating to the equilibrium, or the statical momentum of this fluid, and the latter, to the order of its motion under unequal forces. As the knowledge of these is more particularly connected with the science of mechanics and engineering, they need not be specially dwelt upon here.

Pure water has neither taste nor smell; it is colorless in small bulk, but of a greenish hue when seen in large masses. Water is solid at temperatures below 32° , liquid between 32° and 212° , and gaseous at a higher heat. By a careful method of reducing the temperature of water, and guarding against any agitation of the liquid or contact with any angular body, the point of solidification descends as low as 8° , or even 5° ; that is, 24° and 27° below the point at which it freezes when it is agitated. In like manner, if the ordinary pressure under which it boils at 212° , namely, thirty inches of mercury, be reduced, the phenomenon of ebullition succeeds at considerably lower degrees of heat. Thus it is that on the summit of high mountains, where, in consequence of the elevation, the normal pressure of the atmosphere is lessened, water is observed to boil at a lower thermometric degree than at the base. In the act of solidification water resolves itself into numerous forms, one of which is a rhomboid, closely resembling Iceland spar. Under ordinary circumstances, when its particles are in equilibrium, water is elastic and compressible. This property had long since been proved by OERSTED, and modernly has been established by PERKINS. The results are, however, variously stated: thus, PERKINS found that by a pressure of three hundred and twenty-six atmospheres, the compression amounted to $\cdot 035$ of the bulk, or a value of one hundred and eight millionths for every atmosphere; whereas, when the strain was raised to two thousand atmospheres, the reduction was less than one-half of the above for each atmosphere, namely, forty-one millionths. OERSTED found the average reduction per degree to be forty-five millionths of its bulk; he likewise observed that the contraction increases in direct proportion to the power exercised in compressing it, up to seventy atmospheres. Water is likewise subject to compression and extension when under the influence of another power, namely, that of heat, but with greater irregularity than is observed when acted upon by mechanical force. Generally speaking, the abstraction of heat from bodies serves to bring their particles closer together, and therefore contract them, and *vice versa*; but the axiom is true with regard to water only within certain limits. For instance, when ice is melted by causing it to combine with caloric, instead of expanding with each increment, its bulk suffers a diminution till the temperature of the mass rises to 39.2° , at which degree it has been found to possess its greatest density; on continuing the addition of heat, however, it begins to expand till the boiling point is attained, the acquired bulk in this range being, according to the researches of HALSTROM, one part in twenty-four. The experiment can be easily illustrated by a glass vessel fitted with a narrow tube; the contraction and expansion of the water in the flask being indicated by its descent or rise in the capillary

tube inserted into its mouth. The peculiarity attending a change of temperature in water, between the limits of 32° and 48° may be shown to vary from the expected effects resulting under ordinary circumstances from the addition or abstraction of caloric; thus, the expansion which is observed to take place in the liquid from its point of greatest density, 39.2° , when heated through a range corresponding to that between this and the freezing point, equals exactly that which a reduction of temperature from 39.2° towards the freezing effects, so that the volume at 48° and 32° is exactly the same.

The following table of the contraction and expansion of water between the three points, 32° , 39.2° , and 212° , gives the results arrived at by KORR:—

Temperature.	Volume.	Temperature.	Volume.
32.0	1.000000	69.8	1.001778
33.8 ....	.999947	71.6	1.001995
36.5 ....	.999908	73.4	1.002225
37.4 ....	.999885	75.2	1.002465
39.2 ....	.999877	77.0	1.002715
41.0 ....	.999883	86.0	1.004064
42.8 ....	.999903	95.0	1.005697
44.6 ....	.999938	104.0	1.007531
46.4 ....	.999986	113.0	1.009541
48.2	1.000048	122.0	1.011768
50.0	1.000124	131.0	1.014100
51.8	1.000213	140.0	1.016590
53.6	1.000314	149.0	1.019302
55.4	1.000429	158.0	1.022448
57.2	1.000556	167.0	1.025440
59.0	1.000695	176.0	1.028581
60.8	1.000846	185.0	1.031894
62.6	1.001010	194.0	1.035397
64.4	1.001184	203.0	1.039094
66.2	1.001370	212.0	1.042986
68.0	1.001567		

This peculiar behavior of water is not only interesting as a curious deviation of a natural law, but because it serves purposes of the highest importance in the economy of Nature. The hardest rocks are split asunder by the freezing and expansion of the water which penetrates their fissures, soils are disintegrated, and their hidden elements of nutrition presented in a state fit for absorption by the roots of plants.

When the great body of water of the globe is cooled on the surface, the exposed portion, owing to its density being slightly increased, sinks, causing the warmer substratum to rise, to manifest the same behavior when its temperature is lowered in like manner. Did this circulation continue till the entire mass acquired a freezing temperature, it is evident that the whole body of water would enter nearly at once into the solid state of ice, to the destruction of all living creatures inhabiting it, to the destruction of oceanic commerce, and of the communion of peoples separated by large tracts of oceans and seas. Further, were such the order of the laws governing Nature, not only would the living inhabitants of waters inevitably perish, but those on the land would also be destroyed, in consequence of the insupportable cold that would be produced in the atmosphere, owing to another property which water, whether in the liquid or solid state possesses, of combining with heat, and rendering it latent or insensible. The warmest seasons would be of little avail to counteract such dire effects, and the genial climate of temperate zones would be changed to a far worse condition than

the frigid regions of the North pole! Providentially, however, the progress of the cooling and consequent circulation induced in water by cold is arrested when the whole mass reaches a temperature of about 40° , that is, 8° above the freezing point; for at this limit, instead of contracting and sinking it becomes specifically lighter by expansion, and therefore remains floating on the subjacent mass. By a continued reduction of its temperature the surface will ultimately freeze, and the crust of ice may go on thickening; but it is inconceivable what cold could thus convert the entire mass into the solid form in this way. Hence, even in the perpetually frozen regions of the North, the water beneath the ice retains a heat of 40° —a temperature much higher than is experienced in this climate often during Winter—and suited not only to marine animals, but calculated, under the least favorable change, to aid in bringing about the normal state of things best suited to the wants of the great family of God's creatures.

From the preceding remarks, the cause of ice—solidified or crystallized water—floating in water will be readily understood. It has been shown that at the point of solidification the liquid has the same, if not a lesser density than at 40° ; but, in passing to the solid state, the gravity is much further reduced, as well by the arrangement which its particles assume, as by the expulsion of the gases dissolved in the water, and which, before they can escape, are enveloped and compressed within the solid crystal. From both, and perhaps other conjoint causes, the density of ice at a temperature of 32° is less than that of water at 212° , and hence the former floats in the latter. At the normal degree at which chemists are accustomed to compare the densities of bodies, namely 60° , and a barometric pressure of the atmosphere of thirty inches, pure water is taken as the standard of comparison, and is expressed by unity, or 1000—compared to this ice has a density of 0.916.

Another circumstance which prevents the freezing of the waters of the oceans is the quantity of saline matters which they hold. DESPRETZ found that all such saline solutions have a point of maximum density, which is so far below 39.2° as the solution is richer in salt, and this point of maximum density is even below the freezing point of these solutions when agitated, although in a quiescent state they may be cooled below it without assuming the solid form. The following are the results of his researches on this subject, with solutions of 3.750 parts of the undermentioned compounds in one hundred of water:—

	Maximum density.	Freezing point
Potassa,	21.80	28.22
Carbonate of potassa,	24.89	26.22
Sulphate of potassa,	27.00	28.24
Carbonate of soda,	19.38	26.87
Sulphate of soda,	24.21	27.84
Chloride of sodium,	24.45	27.02
Chloride of calcium,	26.95	26.95
Dry sulphate of copper, ..	30.89	29.63

In considering the effects of heat upon water, a further insight into the beautiful provisions of Nature may be obtained. It has been stated in the preceding that water is the medium by which the great heat of warm climates is assuaged. Here it may be well to explain a little more fully how this is effected. Water, of all

known substances, has the greatest capacity for heat—that is, its power of combining with this imponderable, and exhibiting in a less degree its effects in point of warmth than any other body. This property is possessed by it in its several forms of solid, liquid, and vapor or steam. If a given weight of ice, indicating a temperature of 32° be added to an equal bulk of water at 135° , and the mixture be left at rest till the former is melted, the temperature of the mixture on being essayed will not be the mean of the two degrees of heat— 83.5° —as might be anticipated, but it will be found at the same standard as that of the ice itself before its introduction to the hot water. Hence it is evident that ice, or water, in passing from the solid to the liquid state, renders latent as much sensible heat as would bring it to about half the temperature of boiling water, were it in the liquid state at 32° ; or within 52° of boiling water, were it at the normal temperature of 60° . REGNAULT'S results on this subject are 142.6° , as the amount of heat rendered latent by water in passing from the solid to the liquid state. All this latent heat is evolved from the water in passing to the solid state of ice; and thus does it beautifully serve to soften the rigor of the cold necessarily felt by those in polar climes. In its liquid state, between 32° and 212° , water manifests the same power of uniting with heat, and showing less of its effects sensibly than any other body. For instance, when a pound weight of water at 100° is mixed with the same weight of itself, of olive oil, and of mercury respectively, at 40° , it will be found that the temperatures of the resulting mixtures will not be the same; the mixture of the waters will show the exact mean of their respective heats before mixing, that is 70° ; but that of the water and oil will be 80° , and of the mercury and water will be 98° . Hence it will be seen that the same quantity of heat which in the last instance produced an effect of 2° on water, raised the same weight of mercury 58° ; and that of 20° in the case of the mixture, water and oil, equalled an effect of 40° on the oil alone. The consequences of this capacity for heat are most important in retaining the temperature of bodies at a medium point, and its value to the human frame in hot climates is almost incalculable; for when taken into the system, or evaporated from the parched and inflamed skin of the inhabitants of dry and arid countries, it reduces the heat of the system more than the same weight of any given substance.

When water is evaporated, the caloric which is thus carried off, and with as little sensible effect as that absorbed by the ice during its transition from solid to a liquid, is very great. Water may be boiled in a vessel, and although heat is transmitted to it, during the period of its evaporation, in a continuous stream, yet the heat of the liquid does not rise beyond 212° , nor does the vapor exceed the same necessarily, therefore, the whole of the caloric absorbed must be rendered latent in the vapor formed. This may be proved to be the case by transmitting a given weight of the vapor of water—steam—at 212° into a measured bulk or weight of water at any degree, such for instance as 32° or 60° , and noting the effect. In this way it has been found by DULONG to contain as much as 977.4° of latent heat, which, added to its sensible

caloric, 180° —the difference between 32° and 212° —gives a total of 1157 degrees, or units of heat, possessed by every unit of water in the form of steam at 212° . Without dwelling upon the importance in an industrial point of view of this property which water possesses of combining with heat on assuming the gaseous form, and parting with the same wherever this vapor is transmitted to and condensed, or on the power which an accumulation of the vapor at its normal temperature, or at a higher heat, exercises in the thousands of varied forms in which steam is employed in connection with mechanism and industrial works of arts and manufactures—it will be well to cite this property in further proof of the profound beauty of the conception which, as stated in the introduction, has ordained this to be the medium of modifying the rigor of seasons and the influence of the geographical position of lands. Thus the water which is evaporated within the tropics, and which takes up with it an amount of heat corresponding to 1100° , conveys this heat towards the frigid zones, where, on being condensed either into rain, hail, or snow, it is given out to the air and surrounding objects, and thereby greatly contributes to the mildness and habitableness of those parts. Water evaporates not only at 212° , but at all intermediate temperatures between this and its freezing point; and even when in the state of ice, it has been ascertained that it gives off a very rarefied steam. In all these cases the quantity of heat which it renders latent increases with the degree of rarefaction, so that the same weight of steam, or watery vapor, produced at 60° , contains much more insensible heat than when generated at the boiling point of water.

The chemical relations of water are likewise of the utmost importance. In solvent power, that is, its power of overcoming the cohesion of particles of matter, it has no equal; and this force is exercised in reference to gases and liquids, as well as solid bodies; only that in the case of gases, instead of overcoming the cohesive force of the substance, the reverse is the effect, for it is the repulsive force or their expansion that is, so to speak, neutralized. To this phenomenon of destroying the repulsive force of the particles of gases, and the cohesive in solids or liquids, the term *solution* is applied; and, as is well known, it can in some cases be effected by heat, although in these the change is properly designated *fusion*. Water does not manifest the same behavior, however, with all solids, liquids, and gases, so that it appears the particles of the body capable of being affected in this way, must have a peculiar state of molecular aggregation which holds them together with a force inferior to that which water exerts upon them. There are therefore a numerous class of substances that are not affected at all under ordinary circumstances, and others to a very unequal degree, by water in this respect. For instance, a piece of rock crystal, calcareous spar, or glass, will remain in water a length of time without undergoing any change; but a crystal of sugar-candy, alum, or carbonate of soda, will be found to disintegrate readily, and disappear in the liquid. The former are said to be *insoluble*, and the latter *soluble* substances, in reference to water. Of those which are soluble in water, the quantity of them

which the liquid is capable of combining with, till the equilibrium of the cohesion of the substance dissolved is attained—in other words, the point of saturation of the liquid with such a compound, is very variable, though almost in all cases more or less increased by heat. This may be readily proved by adding to equal weights of water, sugar, salt, or chloride of sodium and gypsum, exposing as great an extent of these as possible to the water by stirring the mixture, and then permitting to rest a while. If the solutions, say one pound of each, be evaporated, and the dry residue weighed, it will be found that the saccharine matter will weigh about twelve ounces, the saline residue about five and a quarter ounces, and the calcareous not more than fourteen or fifteen grains. Again, difference of temperature affects the solvent power of water, increasing it—except in few instances, such as when common salt and gypsum are the subjects, and which are nearly equally soluble in cold and hot water—with each additional degree of heat communicated to the liquid up to 212° ; thus nitrate of potassa is dissolved in water at 57° to the extent of one-fourth, at 92° to that of one half, at 131° to an equal weight, and at 212° to the extent of twice the weight of the water employed. When the solutions made at the higher temperatures, however, are allowed to cool, the particles of the solids, over and above what is taken up at the normal degree, regain their cohesive force, and separate in the form of crystalline bodies. These reactions are of particular importance in a chemical point of view, as they offer a simple and ready means of separation and purification of many substances in various branches of manufacturing industry, the principles of which are governed by chemical laws. Another phenomenon connected with the solution of solids in water is, that in several instances a reduction of temperature takes place; while in other cases heat is evolved. GAY-LUSSAC has explained this anomaly. He found that when simple solution was effected of a salt, whether in a hydrated or anhydrous state, cold, or a reduction of the temperature of the liquid, resulted; but when chemical combination took place between the substance and the solvent, as, for instance, in the production of a definite hydrate, a rise of temperature is experienced. In the former case the salt, in passing from the solid to the liquid form, renders a quantity of heat greater or less according to its capacity for this imponderable, latent, and which is abstracted from the sensible temperature of the water; whilst in the latter the chemical force exerted in the act of combination develops an amount of caloric which is greater than that of the latent heat of the body, and hence the rise of temperature. The simple experiment of dissolving nitrate of potassa or chloride of ammonium in water will, with the aid of an ordinary thermometer, illustrate the truth laid down to the reader as regards the cold produced; and of hydrate or caustic potassa or sulphuric acid in reference to the heat developed. This reaction affords a ready means of distinguishing between chemical combinations with, and simple solution of a substance in water. In all these cases, however, with the exception of simple combination, water effects no change in the substance, so that by evaporation of the liquid, the solid

matter may be again obtained, possessing the properties peculiar to it before solution. There are a few instances, however, in which water does not retain this neutral character; for with some of the salts of bismuth, antimony, and tin, its addition produces a decomposition, causing a liberation of the radical or acid of such, while itself in part undergoes decomposition. The reader will find these examples of decomposition illustrated under the respective metallic salts referred to.

To enter into the behavior of water with the alcohols, ethers, oils, resins, and other matters, would prolong the subject beyond prescribed limits; suffice it to say, that when alcohols partake of the nature of oils, they are not at all soluble in it; neither are ethers and oils, in the ordinary acceptance, dissolved by water; nor are the resins. Alcohol—that resulting from the fermentation of saccharine matters—is soluble in it in all proportions, although ether, the derivative of this body, and differing from it only by the elements of one equivalent of water, is almost insoluble in the liquid.

Behavior of Water with Gases.—Not only has water the property of liquefying a great number of solid bodies, but it exercises the same function with respect to many gases; a property that is of very great importance in the economy of nature in many instances.

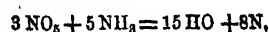
To convey an adequate conception of the solvent power of water for gases, it may be stated that one hundred cubic feet, or six hundred and twenty-five gallons of water, at 60° and a barometric pressure of thirty inches, will dissolve of—

Hydrochloric acid gas,.....	50000.0	cubic feet.
Ammonia,.....	67000.0	"
Sulphurous acid,.....	5000.0	"
Sulphuride of hydrogen,.....	800.0	"
Chlorine,.....	200.0	"
Carbonic acid,.....	100.0	"
Carbonic oxide,.....	6.6	"
Binoxide of nitrogen,.....	5.0	"
Oxygen,.....	4.6	"
Nitrogen,.....	2.5	"

Water which has been much exposed to the air, such as rain water, absorbs two and a half parts of that compound; and what is so curious regarding it is, that the amount of oxygen in such, instead of being only twenty-one per cent., as in the atmosphere, was found to be so high as 34.8 per cent. by GAY-LUSSAC and HUMBOLDT. BOUSSINGAULT found that at an elevation of six to eight thousand feet, water absorbs not more than one third of the volume of air which it liquefies on the plain; which behavior has been cited as the cause of fishes not being found in the Alpine lakes situated at comparatively high altitudes; the small amount of oxygen in the soluble state in the water being thought insufficient to support the respiration of these cetaceous animals.

Many natural waters contain considerable quantities of nitrogen. PLAYFAIR estimated that the famous Buxton water, as it issues from the spring, is in combination with nearly three-fourths of its volume of nitrogen—as will be hereafter more discussed under its analysis. With so unnatural a phenomenon, the question, *Whence does it come?* at once intrudes itself. That it is assimilated from the air is impossible; and it is hardly conceivable that the water in passing through

the calcareous strata of the district should meet with or take up such quantities of nitric acid and ammonia as would, by their mutual decomposition in some such manner as the following—



give rise to the forementioned volume of gas.

Before entering upon the consideration of natural waters with respect to their hygienic qualities, *et cetera*, it may be stated that pure water at 62° and thirty inches barometric pressure, is taken for the standard to which the relative density of all other solids and liquids is compared; just as air is adopted as the standard for measuring the gravity of gases, both being assumed unity, or 1000. At the above degree of heat and pressure, one hundred cubic inches of it weigh 252.45 grains; consequently the imperial gallon weighs 70.000 grains, or ten pounds avoirdupois. It is eight hundred and fifteen times heavier than air, and one thousand three hundred and four times the weight of an equal bulk of its densest vapor, steam, generated at 212°. Its composition is represented as being one equivalent of hydrogen and one of oxygen—HO—and it has been found to contain—

	At. weight.	Centesimally.
1 Eq. hydrogen,.....	1	11.1
1 Eq. oxygen,.....	8	88.7
	9	100.0

NATURAL WATER.—By this term is understood the ordinary liquid which serves the purposes of every-day life, whether its source be the rain, hail, or snow, which falls from the atmosphere; the drainings of the surface of the country, accumulated in lakes or rivers; well, or natural springs, through which the liquid permeating the porous strata of the earth at one place, finds an outlet or lower hydrostatic level at another; and sea or salt water. For the sake of clearness in the details which the Editor intends to lay before the reader on this subject, its consideration will be made in the following order, namely, rain, surface—including lakes and rivers—and spring or well waters, all embraced under the class Fresh Water; and Sea Water, or such waters as contain an abnormal quantity of foreign ingredients, and are therefore unfit for the more general uses to which this liquid is applied.

FRESH WATERS.—*Rain and other Waters immediately derived from the Atmosphere.*—As already stated, there is a continual evaporation of water taking place from the surface of the land and sea, which is greater in warm latitudes, and lesser in the parallels approaching the frigid zones and the poles of the earth. This evaporation is dependent, in the first instance, on that curious property of gases, discovered by DALTON, by which a space filled with one kind of vapor or gas, offers as little obstruction to the diffusion of another vapor or gas, in the same space, as if it were already a vacuum; and in the second, upon the temperature. Some other conditions likewise affect the evaporation of water spontaneously, such as the quantity of moisture already contained in the atmosphere, the force and direction of the winds, *et cetera*, which need not be followed. Whilst the heat at which it

was converted into an elastic vapor remains the same, watery vapor is quite as invisible as the air; but on sudden changes of temperature, occasioned by being brought into contact with a colder body of air, or any cooling surface, then the moisture is first condensed into very minute drops, forming clouds, and these drops continue to aggregate among themselves till their gravity becomes greater than the air, and they fall to the earth as refreshing rain. The theory of HUTTON, with respect to rain being produced by the mixing of opposite currents of air at different temperatures, though true to some extent, appears to be inadequate to produce the amount of rain which the numerous meteorological observations so generally made during late years have registered; and it is therefore supposed that more rain is formed in close proximity to the earth, than in the higher regions of the air. The experiments of Professor J. PHILLIPS corroborate this in an extraordinary manner. He found that the fall of rain on the—

Top of York Minster, 242 feet high, was 15·910 inches.		
Roof of Museum, 73 "	20·461 "	
Surface of ground, 0 "	24·401 "	

That all the rain of these latitudes could not be produced on Dr. HUTTON's principle, may be readily conceived by considering the circumstances a little in detail. The tension of the vapor of water at 59° equals 0·5000 of an inch of mercury, and at 41° 0·2573; now, if equal bulks of air at these temperatures, saturated with water, commingle, the mean temperature of 50° will be attained, at which the tension of the aqueous vapor is 0·3608, the difference between which and 0·3786, the mean of the tensions above indicated, that is, 0·0178, represents the tension of the amount of water that would be condensed from the state of vapor. This quantity is very inconsiderable compared with that resulting from atmospheric changes which take place on or near the earth, as may be seen from the following example, quoted from GRAHAM. The mean temperature of January in this country is about 34°, but with a South-west wind the thermometer may be observed to rise gradually in the course of forty-eight hours to 54°; now, supposing such wind to be saturated with aqueous vapor, and that in traversing over the surface of the land it is cooled to 34°, the amount of moisture which it must deposit will be very considerable, as appears by the following—

Tension of vapor at 54° equal to 0·429 inches mercury.	
Do. do. 34° "	0·214 "

Difference condensed as rain, 215 "

Invariably there is the greatest average fall of rain near the equator; it diminishes towards the poles, as the latitude is higher. The average annual fall of rain at—

New Granada, 12° 0' N.....	is 126 inches.
Calcutta, 19° 46' N.....	81 "
Rome,.....	39 "
England, average.....	31 "
London,.....	23 "
St. Petersburg,.....	16 "
Uleaborg,.....	13½ "

Snow and hail is a form of rain, in which the water is frozen before it reaches the earth; the former results from the formation of clouds at temperatures below 32°, wherein the minute drops are crystallized into an infinity of spiculæ, which arrange themselves into regular lines and figures, diverging from one another at angles of 60° and 120°. They are all referable, however, to the hexagonal and prism shape, though the details differ in almost every storm.

Hail is supposed to be formed in warm weather, when the sun is above the horizon, and under different circumstances to those calculated to produce snow. It is supposed to be produced in the ascending current of greatly rarefied air, by the cold consequent on such rarefaction, the force of the upward current being such as to carry with it the minute solid globule, till, by uniting with others, it attains a density that causes it to descend. Generally, this phenomenon of the production of hail is associated with a peculiar electrical state of the atmosphere, to which it must be principally attributed.

Rain, as it descends from the clouds, is contaminated with various gases and vapors which it dissolves from the air. The atmosphere, normally composed of oxygen and nitrogen, contains vast quantities of ammonia, carbonic, nitrous, and nitric acids, besides other gases and vapors which arise from the number of chemical phenomena which are ever taking place on the surface of the earth. The principal of the *abnormal* gases is *carbonic acid*—a gas which escapes in enormous quantities from volcanic districts, and which results also from respiration, from the combustion of fuel, and decay of organic matter and vegetal growth generally, on the surface of the earth. Though analysis detects only about one thousandth of this gas in the air, still when the total bulk of the latter is taken into consideration, the entire weight of carbonic acid disseminated in it is enormous, averaging more than *five billions of tons!* The air likewise contains much ammonia and vapors of the oxides of nitrogen, besides other unknown gases and vapors, which escape from decomposing animal and vegetal matter.

All the gases which have been detected in atmospheric air are exceedingly soluble in water; hence it follows, that rain-water, as it descends through the lower strata of the air, must become to a great extent impregnated with these gases. LIEBIG has shown that even snow contains much ammonia, and recently in some rain-water, collected on Brighton Downs, MEDLOCK detected this gas, and also traces of the acids of nitrogen, which had probably resulted from the oxidation of a portion of the volatile alkali. It is, therefore, evident that water as it falls from the clouds, whether in the form of snow or rain, is not absolutely pure, but contains much carbonic acid and ammonia. Probably traces of other gases, which have hitherto eluded detection, are likewise present. Not only is ammonia present in snow and in rain, but HORSFORD even detected it in large quantities in the ice from the Glacier de Boisson, at a height of twelve thousand feet above the level of the sea; and MEDLOCK has found marked quantities of this volatile alkali in the purest and most transparent masses of ice from the Wenham Lake in

America. The presence of ammonia in rain-water has not long been known; and it is one of the main causes of the fresh and invigorating influence of it upon the vegetal creation.

SURFACE WATER.—Rain-water is a very powerful solvent of certain ingredients of the soil, such as sulphate of lime, chloride of sodium, and magnesian salts; but when saturated with carbonic acid, as is ordinarily the case, its solvent properties are remarkably increased. For example, ordinary water, free from carbonic acid, will not dissolve more than a grain of chalk per gallon; but when saturated with that gas, the same quantity will dissolve upwards of two hundred grains. In like manner it is found that carbonate of magnesia, which is almost entirely insoluble in ordinary water, will dissolve in water impregnated with carbonic acid in very considerable quantity. Hence, in addition to the alkaline chlorides and sulphates, and sulphate of lime, nearly all spring-waters are found to contain carbonates of lime and magnesia, which are held in solution as bicarbonates by the carbonic acid derived from the soil and atmosphere. Certain of the mineral constituents impart to water its *hardness*. These are the salts of lime and magnesia. By the hardness of a water is understood the power it possesses of decomposing soap; and according to the quantity of soap decomposed by a given quantity of water before the remaining soap becomes available as a detergent, so is its relative hardness. The sulphates, chlorides, and nitrates of lime and magnesia give to the water the so-called *permanent* hardness, while the carbonates, which are held in solution by excess of carbonic acid, impart to it its *temporary* hardness, or that which it loses by boiling.

The waters of rivers, from which the greater number of English cities and towns obtain their supplies, contain the above-named mineral constituents in quantities varying according to the composition of the soil over which they flow. In the water of streams which have their sources in the primitive rock formations, as, for instance, the rivers Dee and Don, there is found only from two to eight grains of mineral constituents per gallon. The water of the Trent, which flows through a *selenitic* district, contains about sixty grains of sulphate of lime; while in the water of the Thames, which is derived from, and flows over a chalk formation, there are only about three grains of sulphate, and from eight to ten grains of carbonate of lime per gallon. For the sake of comparison, and in illustration of the above statement, the analyses of the Thames, Trent, Dee, and Don are given:—

	Thames water.	Trent water.	Dee water.	Don water.
Carbonate of lime,	10.80 ..	0.32 ..	0.85 ..	2.23
Sulphate of lime,	3.00 ..	21.55 ..	0.12 ..	0.18
Nitrate of lime,	0.17 ..	.. ..	.. ..	..
Carbonate of magnesia, ..	1.25 ..	5.66 ..	0.86 ..	1.07
Chloride of sodium, ...	1.80 ..	17.63 ..	0.72 ..	1.26
Silica,	0.56 ..	0.72 ..	0.14 ..	0.52
Iron, alumina,	0.27 ..	0.50 ..	0.06 ..	0.27
Phosphate of lime,	trace ..	trace ..	trace ..	trace
Organic matter,	2.36 ..	3.68 ..	1.64 ..	3.06
	<u>20.21</u>	<u>50.06</u>	<u>3.89</u>	<u>8.54</u>
Hardness,	14.00	26.50	1.50	8.00

From the preceding analyses it is evident that the proportions of mineral constituents are, in a great measure, dependent upon the nature of the soil over which the water flows. Although the opinions of chemists differ widely regarding the hygienic effects of an access of the mineral constituents in water, the Editor is inclined to believe—and this opinion almost universally prevails—that so long as the proportion does not exceed thirty grains per gallon, they are decidedly more beneficial than injurious. The sense of taste is perhaps the best guide; and so long as preference is given to a water containing mineral matter to such as are almost entirely free therefrom, it may be assumed that such waters are the best for general purposes.

These remarks apply equally to the waters derived from wells. Indeed, in all the water supplied for man's use there are found the above-mentioned mineral constituents. Are they there for no purpose? Would Nature contaminate water with constituents injurious to health? It has been already mentioned that such waters as contain a certain proportion of mineral constituents, are much more refreshing and agreeable to the taste than those in which they are absent. The remarkable investigations of modern chemists have shown incontestably that a certain proportion of mineral elements in food is absolutely necessary for the due performance of the vital functions. In milk, man's natural food, there are all the elements necessary for the formation of the body—phosphate of lime for the formation of bone; salts of soda to aid in the formation of the gastric juice, and to give fluidity to the blood; casein to form the flesh; and butter to produce fat. In all the cereal grains and in the vegetables which constitute the chief food of gaminivorous animals and of man, there are found the *same* mineral constituents which occur in water—*man's natural drink*. Who, then, can deny the value of mineral constituents in the water of wells and rivers? When in very large excess, as in the *shallow* well-waters of London—an exception to the rule—they may, perhaps, tend in some measure to derange the digestive organs of delicate persons, especially of those who have been accustomed to the use of softer water—that is, such as contains less earthy salts—for dietetic purposes; but in most cases in which hard waters are found to disagree, the objectionable effects may, in all probability, be ascribed with greater truth to *organic* impurities than to the actual *mineral* constituents. Having thus briefly alluded to the physiological effects of the mineral constituents of water, it becomes necessary to enter more fully into the nature of the more abnormal *organic* contaminations to which the water of wells and rivers is exposed, since on these is essentially dependent the hygienic character of the water—its fitness for domestic purposes.

NATURE OF THE ORGANIC MATTER CONTAINED IN WATER.—All river and well waters contain more or less of organic matter, which is acknowledged to be a predisposing cause of disease. The separation of these impurities from water is a problem of high scientific interest, and one that has engaged the attention of all the eminent chemists of the day.

The great importance of this subject in a sanitary

point of view renders it necessary to enter into detail regarding it:—

1. The source of organic matter.
2. The nature of the decomposition it undergoes.
3. The means of destroying the organic matter and rendering the water pure and wholesome.

1. *The Source of Organic Matter.*—A river is the natural drain of the country and towns through which it flows, and the organic matter the water contains must necessarily be derived from the three following principal sources:—

From the sewage of towns; from the surface drainage of manured and cultivated lands; and from the decay of the aquatic plants and animals which inhabit the streams.

The sewage of towns consists mainly of the urine and fæces of man and animals, the refuse of gas-works and numerous manufactories, which are diluted with the refuse water which has been used for domestic and manufacturing purposes. The Thames, which may be taken as a type of other rivers, before it reaches London drains an area of four thousand square miles, and receives in its course the sewage of towns containing upwards of seven hundred thousand inhabitants. It flows, moreover, through a richly cultivated country, from which it derives vast quantities of organic matter. It is further contaminated with the products resulting from the decomposition of aquatic plants and animals. Hence it is obvious that the water of the Thames, even before it reaches Toddington lock, must be most seriously contaminated with putrefactive organic matter. That much of the organic matter which enters the river is spontaneously decomposed is undoubted, otherwise the river would be little better than a filthy sewer; but that a vast quantity remains in solution in the water as now supplied to the inhabitants of London, is equally a demonstrable fact, as will be seen by the analyses and experiments detailed in the following pages.

Most, and indeed all the companies who take their supply from the Thames, filter the water through sand and shingle previously to pumping it into the mains. By this means most of what exists in it in the form of undissolved or *mechanically suspended particles* is removed, and the water is consequently to some extent improved in appearance. But the greater part of the organic matter is *dissolved* in the water, and is not separated by mere filtration. That much organic matter exists in the present supply is evident from the decided color which the water possesses. This is also the case with the Pike water at present supplied to Liverpool.

If a tall tumbler be filled with any of the water now supplied to London, Liverpool, Manchester, and other towns, and placed on a sheet of white paper, the water will be seen to possess a yellowish or brownish tinge, occasioned by the *organic matter which is held in solution*. The removal of this organic matter, which is doubtless a fertile source of disease in those who daily drink it, is a problem of the highest interest to solve, and one to which MEDLOCK has devoted several years in the hope of its elucidation. Accident in some measure led him to follow out an inquiry into this subject,

which promised to lead to most important results, and the Editor deems the circumstances which suggested this investigation worthy of being recorded; especially as the results arrived at by accurately conducted experiments are not only of high scientific interest in themselves, but, practically applied, are of great hygienic and national importance.

In September, 1856, he was requested by the directors of the Amsterdam Water Company to analyse several samples of water from the city of Amsterdam. Complaints had been made of the water by several of the inhabitants. It possessed a peculiar *fish-like* smell; and although perfectly transparent and colorless, and free from the slightest chalybeate taste, it was found, after standing some time, to deposit a reddish-brown sediment, which coated every vessel in which the water was placed.

The service-pipes being of iron, the deposit was assumed to consist of the sesquioxide, resulting either from the decomposition of a protosalt of iron in solution, or from the attrition of the iron pipes through which the water was conveyed.

It may be observed that Amsterdam is supplied with water from the *Dunes*—sand-hills—in the neighborhood of Haarlem. Trenches, five miles in length, have been dug on the sides of the hills, to intercept the rainfall. The water is conveyed to a large reservoir, whence it flows to the filterbeds at the works, and is there filtered through four feet of filtering medium, consisting of pebbles, shells, and fine sand. After filtration it is pumped up an iron standpipe one hundred and fifty feet high, and conveyed thence by iron mains to Amsterdam, a distance of eighteen miles.

Five samples of the water were sent for analysis—one from the works *before the water came in contact with iron*; the other four from various standpipes in the city.

In the water from the works, before it came into contact with iron, the quantity of iron oxide, alumina, and phosphates amounted to 0.95 grain per gallon. In the analysis of the four other samples, *after passing* through eighteen miles of iron pipes, the quantities were reduced in the several determinations to 0.09, 0.07, and 0.07 grain, and in the fourth sample to an unweighable trace. Thus, instead of taking up an additional quantity of iron oxide from the mains and service-pipes, the water was found actually to have lost nearly the whole of the iron which it previously held in solution; but, notwithstanding the almost entire precipitation of the iron actually in solution in the water which had passed through iron pipes, it formed the objectionable red deposit on standing, while the water from the works, holding in solution nearly half a grain of iron oxide per gallon, formed no such deposit: therefore it was, *a priori*, to be assumed that the red deposit could not consist of oxide of iron, and consequently it appeared necessary to examine this deposit very carefully both chemically and microscopically. The precipitate from ten gallons of water was collected in a porcelain capsule, evaporated to dryness on a water-bath, and heated subsequently in an air-bath to 248° Fahr., until it ceased to lose weight. On ignition, the precipitate *charred* and

was almost entirely consumed, leaving only a minute quantity of ash, consisting of silica, alumina, iron oxide, and carbonates of lime and magnesia.

The small quantity of this deposit at command did not admit of a quantitative analysis. The deposit having been found to consist almost entirely of organic matter, a portion of it, which had been separated from one gallon of water, was examined under the microscope, and was seen to consist of the filaments of dead and decaying algæ, confervæ, and other microscopic plants in various stages of decay, and varying in color, like autumnal leaves, from green through pale-yellow, orange, red, brown, dark-brown to black. Many of the fibres retained a perfectly organized structure, and in some the spores, by which these plants are propagated, were distinctly visible. Amongst these plant remains were numerous silicious tubes, which had probably invested the delicate filaments of the algæ while living.

It appeared highly important to determine the cause of the precipitation of the organic matter from the water which had been in contact with the iron pipes; and in the hope of elucidating this interesting question MEDLOCK proceeded to Amsterdam to inspect the source of supply and the works. As anticipated, the Dune canals were found to be actually choked up with aquatic plants, and at the sides and wherever the current was sluggish were large masses of dead algæ floating on the surface. The sand at the bottom, originally very white and pure, was blackened to some depth by decaying vegetal matter, and, when disturbed, numerous bubbles of fetid marsh gas escaped.

The water had the peculiar fish-like smell of the masses of *flab-ulva intestinalis*—floating on the surface. The stones on the sides of the canals, the hurdles placed to keep up the banks, floating pieces of stick, and indeed every solid body with which the water came in contact, were coated with a reddish-brown deposit, similar to that which was found to separate from the filtered water in Amsterdam. *This deposit was observed to be particularly abundant near the iron sluice gates.* A pipe from one of the mains in the city was examined at the same time, and found to be coated on the inside with a thick slimy deposit of vegetal remains, which presented under the microscope an appearance exactly similar to that of the deposits above alluded to.

Remembering the important fact established by SCHÖNBEIN, that copper and platinum in a finely divided state have the property of converting ammonia into nitrous acid; and MEDLOCK having demonstrated that lead in any form possesses a similar power—it occurred to him that if the same property were possessed by iron, it would throw some light on the separation of the organic matters from waters which are placed in contact with that metal. SCHÖNBEIN, however, states that iron, before it produces a similar oxidizing effect on the ammonia, requires to be heated to redness. But in the course of an extensive series of experiments, it has been found that iron pyrophorus instantly transforms ammonia into nitrous acid; and in pursuing the inquiry further, it was found that strips of sheet iron placed in water containing ammonia or

organic matter capable of yielding it, act almost as energetically as the metal in a finely-divided state.

Having proved that metals possess this remarkable power of oxidizing ammonia, and converting it into nitrous acid, and, bearing in mind the extraordinary oxidizing power of this acid, even when present in minute quantities, it appeared to MEDLOCK that he had arrived at a simple and effectual means of depriving water of all organic impurities by thus accelerating a natural process of decay. The facts just mentioned appeared to merit a thorough investigation, and the results arrived at will sufficiently prove that he did not, in the first instance, attach too much importance to them. In order to study the action of iron upon the Amsterdam water, he submitted to analysis a quantity of this water which *had never been in contact with iron*, and at the same time he immersed several coils of iron wire in two gallons of the same water. The water in which the iron wire was placed was perfectly bright and free from color, and had nothing visible in mechanical suspension except a few of the siliceous tubes already alluded to. The experiment was made in four open glass bottles. A series of remarkable phenomena were observed. In five minutes a faint white cloud was seen radiating from the coil of wire, and descending in the form of a parachute. In half an hour the cloud had increased in density, and the water became opalescent. In six hours the cloud assumed a brownish color, and there was a brown deposit at the bottom of each of the bottles. The cloud continuing to increase during forty-eight hours, assumed more and more a flocculent character, and a reddish color, exactly like the deposit from the water which had flowed through the iron pipes. The water was now filtered through fine Swedish filter-paper and submitted to analysis, and a portion of the deposit examined under the microscope. The latter consisted of the remains of algæ, each separate flock having a siliceous tube as a nucleus. The remainder of the deposit was burned, and the ash found to consist of oxide of iron, silica, and the carbonate of lime and magnesia.

The following are the analyses of the water before and after being in contact with iron:—

	I.		II.
	Water from the Dune canals.		Same water, having been in contact with iron forty-eight hours.
	Grs. per gal.		Grs. per gal.
Sulphate of lime,.....	3.70	....	3.68
Chloride of sodium,.....	4.10	....	4.01
Carbonate of lime,.....	5.60	....	5.20
Carbonate of magnesia,.....	8.97	....	1.30
Silica,.....	0.16	....	trace
Iron, alumina, and phosphates,	0.95	....	trace
Matter, volatile on ignition—so called organic matter,.....	2.10	....	trace
	20.58	....	12.19

By these analyses it is seen that the 2.10 grains of organic matter contained in the water were decomposed or thrown down by contact with iron. The water, thus purified, no longer had the unpleasant fish-like taste and smell which had marked its previous contamination.

A portion of the water which had been in contact with the iron wire was rendered slightly alkaline by

pure alcoholic potassa, evaporated to dryness, and the residue tested for nitrous acid. The paper became instantly blue from the liberation of a trace of the nitrous acid formed by the oxidation of ammonia, and which had been instrumental in destroying the organic matter.

In the residue of the water which had not been in contact with iron and still containing its organic matter, no indication of nitrous acid could be obtained.

The Amsterdam water, the water of the Thames, and indeed that of nearly all other rivers, contain much organic matter, which may be divided into two classes—*nitrogenous* and *non-nitrogenous*. The latter, consisting of carbon, oxygen, and hydrogen, may be represented by the general formula— $n(\text{CHO})$; and, when no longer under the mysterious influence of the vital force, are rapidly resolved into carbonic acid and water. The nitrogenous class being chiefly of animal origin, and composed, in addition to the above-mentioned elements, of nitrogen, sulphur, and phosphorus, may be represented by the general formula— $n(\text{CHONSP})$. Now, when animal matter decays, and when dissolved in water, decomposition proceeds very rapidly; beside carbonic acid and water other and very offensive products are eliminated. As a general rule, the carbon unites with oxygen to form carbonic acid; and with hydrogen, to form marsh gas or carbide of hydrogen; hydrogen and oxygen unite to form water; nitrogen and oxygen with hydrogen to form ammonia; sulphur with hydrogen to form sulphide of hydrogen; phosphorus with hydrogen to form phosphide of hydrogen.

The latter two are exceedingly offensive to the sense of smell, and are, moreover, highly poisonous. Thus in the spontaneous decomposition of the organic matter contained in water there are produced carbonic acid, carbide of hydrogen, ammonia, sulphide of hydrogen, and phosphide of hydrogen. These are the *recognized* compounds; but when it is borne in mind that the gaseous emanations of decomposing animal matters are infinitely more offensive to the sense of smell and injurious to health than any of the gases above mentioned, or of any combination of them, it can only be concluded that the effluvia of decaying organic matter contain other constituents, of which the true character has not yet been determined. Thames water, if allowed to stand in an open vessel for a few days in warm weather, acquires a very offensive odor, arising from the decomposition of the animal and vegetal matter which it holds in solution.

This water, notwithstanding, is considered by maritime authorities to be the very best for the use of ships' companies. On board ship the water is stored in wooden casks, which are placed low down in the hold. During the first week or fortnight, according to the temperature of the atmosphere, the water ferments, evolves a quantity of gas of offensive odor, and deposits a copious brown sediment. The water gradually ceases to smell badly, becomes bright and sparkling, and will then keep fresh and sweet for an indefinite length of time. In other words, it loses by a natural process of decay, the whole of its *putrescent impurities*. In vessels of war, and in most of the large steamers, tanks of iron have been substituted for casks of wood for storing

the water necessary for the use of the passengers and ship's company. In iron tanks Thames water evolves *no offensive gases*, but becomes much *purier* than when stored in wood, and deposits a more copious brown sediment, which turns red on exposure to the air. The gases produced in the wooden casks are said to be slightly luminous in the dark, and to explode when a lighted candle is incautiously placed near the bung-hole, when the plug is removed. The luminosity is due to phosphide of hydrogen, and the explosive character of the gases to carbide of hydrogen.

As the organic matter was found to be so effectually removed by iron from the Amsterdam water, MEDLOCK instituted a series of experiments upon the water of the Thames. The water operated upon was that supplied to his laboratory by the Grand Junction Company. On placing some of this in contact with iron in glass bottles, precisely similar phenomena were observed as in the case of the Amsterdam water, but the deposit was *black*, and was formed more quickly. The next step in the investigation was to test the water before and after contact with iron for the great destroying agent, NATURE'S SCAVENGER, *nitrous acid*. The residues of six separate gallons of the water were examined for nitrous acid as follows:—Each residue, mixed with half an ounce of water was introduced into a Florence flask, fitted with a cork and loup funnel tube. In the neck of each flask was placed a slip of bibulous paper, moistened with starch paste and iodide of potassium. Through each funnel tube was added half an ounce of dilute sulphuric acid, one part strong acid, and nine parts water, to liberate the nitrous acid, if present; but no indication of that gas was found, as the test papers remained perfectly white. Six other gallons of water drawn at the same time, were placed in open bottles, with two ounces of fine iron wire, and left for forty-eight hours. The waters were then filtered from the deposits, evaporated to dryness, and tested for nitrous acid in a manner similar to the preceding, and with the following results:—

- Experiment 1.—Paper becomes blue in ten minutes.
 " 2.—Paper becomes blue in five minutes.
 " 3.—Paper becomes blue in four minutes.

As it appeared probable that the nitrous acid liberated by the sulphuric acid might remain in solution, and in consequence not instantly affect the test-paper, in experiments with the residues of the other three gallons of the water *hot water* was used, and an acid of double strength. In each of these experiments the test-paper became blue in a few seconds.

These results prove beyond a doubt the production of nitrous acid by the action of iron upon the nitrogenous compound contained in the water. The Editor submitted masses of the Pike water to a similar treatment, and found results that confirmed in every respect those attained by MEDLOCK. Why is not this plan of purification adopted by the Water Committee in Liverpool?

EXAMINATION OF THE BROWN DEPOSIT PRODUCED BY IRON.—The brown deposits from three separate gallons of Thames water were collected in porcelain crucibles, and dried at 248° , till they ceased to lose

weight. When thoroughly dried they weighed as follows:—

NO. I.	NO. II.	NO. III.
4.4352 grains.	4.4243 grains.	4.4350 grains.

They were then separately analysed with the following results centesimally:—

	I.	II.	III.
Organic matter,.....	22.92	24.87	23.87
Sesquioxide of iron,....	65.86	63.20	64.39
Carbonate of lime,.....	11.11	11.04	11.20
Carbonate of magnesia, traces		trace	
Silica,.....	0.59	0.49	0.53
Loss,.....	0.02	0.31	0.01
	100.00	100.00	100.00

In order to arrive at a correct knowledge of the action of iron upon Thames water, MEDLOCK made a series of daily determinations of the mineral residue and organic matter in the water supplied to his laboratory, with the following results:—

	Solid residue, Grs per gallon.	Organic matter Grs per gallon
Jan. 4th, 1857,.....	20.867	2.248
Jan. 5th, 1857,.....	19.573	1.740
Jan. 6th, 1857,.....	21.159	1.424
Jan. 7th, 1857,.....	20.127	1.401
Jan. 8th, 1857,.....	21.452	3.249
Jan. 9th, 1857,.....	20.374	2.756
Jan. 10th, 1857,.....	20.920	3.062
Average,....	20.638	2.268

At the same time as the water was drawn for the last analysis, he placed three separate gallons in wide-mouthed bottles.

Into the first gallon was put a coil of fine iron wire, weighing half an ounce. After standing two hours the water was filtered, and on being analysed in the usual way, gave—

Solid residue,.....	17.372 grains.
Organic matter,.....	1.232 do.

A second gallon with one ounce of wire for two hours gave—

Solid residue,.....	16.693 grains.
Organic matter,.....	1.170 do.

A third gallon with eight ounces of wire for two hours gave—

Solid residue,.....	13.182 grains.
Organic matter,.....	0.950 do.

In other experiments, too numerous to detail, the water was exposed to the action of a large surface of iron from twelve to forty-eight hours; and as a general result it was found that by allowing water to remain in contact with a large surface of iron for about twelve hours, every trace of organic impurity was destroyed, or converted from the soluble to an insoluble condition, in which state it admitted of being effectually removed by ordinary filtration.

After the preceding details on the nature of the organic impurities contained in ordinary well and river water, the offensive gases arising therefrom, and the functions of the numerous microscopic plants and animalcula which are contained in them, it now remains to describe the means that MEDLOCK has adopted for

placing the results of his discoveries at the service of the public.

PRACTICAL APPLICATION OF THE FOREGOING PRINCIPLES.—It has been proved by numerous trials with Thames water, sewage, and water artificially contaminated by mixing therewith sulphide of hydrogen, sulphide of ammonium, and urine, that however impure a water may be, it can be rendered perfectly pure and wholesome to drink by merely allowing it to remain in contact with a large surface of metallic iron for twelve or twenty-four hours, and then filtering through well-washed sand; or, better still, through a mixture of about one part animal charcoal and four parts sand.

The plan above stated is applicable to the purification of the supply of water to towns, as well as to small quantities for domestic and manufacturing purposes. To brewers, dyers, starchmakers, soda water and lemonade manufacturers, *et cetera*, a supply of water free from color and organic impurities is an essential requisite; and the Editor after long and careful study of the numerous processes recommended for purifying water, prefers the one above detailed, as being at once the most simple, easy, and effectual.

The following table exhibits in round numbers the degrees of impurity in water, used for the supply of towns in England, Scotland, *et cetera*, each degree being equal to one grain per gallon—

Distilled water,.....	0°
Loch Katrine,.....	2.0
Dee—Aberdeen,.....	4.0
Tay—Perth,.....	5.5
Dunfries,.....	7.0
Gorbals,.....	8.0
Leven,.....	8.5
Clyde,.....	9.5
Tyne—Newcastle,.....	11.0
Tweed—Coldstream,.....	11.5
Seine—Paris,.....	12.0
Liverpool well, purest,.....	13.0
Glasgow “ “.....	15.0
Kilmarnock,.....	15.0
Thames—1854,.....	15.5
“ —1851,.....	21.0
Glasgow well, most impure,.....	36.0
Liverpool well, “.....	417.0

Disease occasioned by the Organic Impurities of Water.—Dr. HASSALL remarks—In proof that water highly charged with decomposing organic matter frequently gives rise to severe and fatal diseases, often of an epidemic character, one is able to produce abundance of evidence. To occasion these effects, no doubt the organic matters, animal or vegetal, resolve themselves into carbide, sulphide, and phosphide of hydrogen, cyanides, *et cetera*, as well as other lethal products, and these disarrange the whole functions of the body. To enter more minutely into this part of the subject would be out of place in a technological work.

Disease occasioned by the Metallic Impurities in Water.—The Editor has known most serious illnesses to arise from water containing lead. Many hard as well as soft waters act injuriously upon lead, consequently, as a general rule, water should never be stored in cisterns of this metal. Why use lead when one can have slate cisterns and enamelled iron pipes? A

gentleman and his family residing in the neighborhood of Liverpool were constantly ill, but whenever they left home they recovered. The water was supposed to be the cause, and was tested from time to time, and pronounced good. The amount of lead was small, and had been overlooked—as is very often the case with inexpert analysts. On examination of several gallons of the water—it was a remarkably soft water—lead was detected. The Editor recommended slate cisterns and enamelled iron pipes, and from that day to this all the ill effects of the water disappeared.

Microscopic examination of Water.—Most well and river waters, when allowed to stand in an open vessel for several days, especially in warm weather, deposit a sediment more or less copious, in which may occasionally be discovered, by means of a microscope, a vast number of the lower forms of animal and vegetal life, which have been made the subject of special study by several able microscopists, and especially by Drs. HASSALL and LANKESTER. Much misapprehension, however, appears to prevail regarding the extent to which these lower forms of organic life occur in water. In works treating on this subject, it is usual to group a large number of these objects together in a circular drawing, which convey the impression, and are generally understood to represent the animalcula contained in a single drop of water. Nothing, however, can be more erroneous, and nothing more calculated to convey false notions regarding the character of the water supplied to the public.

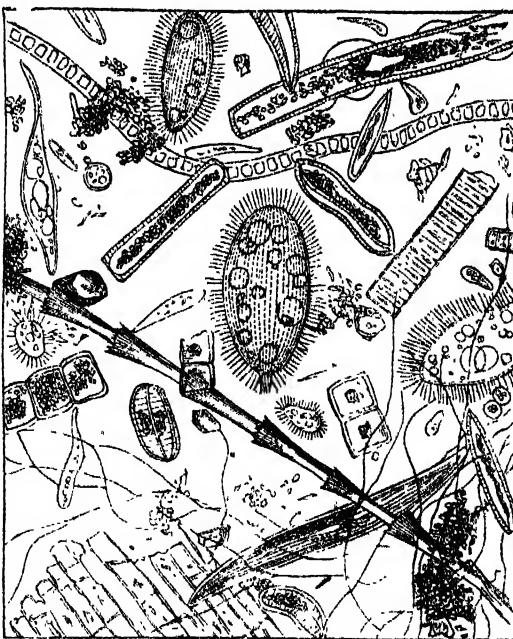
It appears to be a law of nature, that wherever the conditions of life exist, there life will manifest itself in forms suited to the circumstances. If a portion of earth be brought up from the deepest mine, and exposed for some time to the combined influence of heat, light, and moisture, various forms of vegetal and animal life will appear, even if the soil be entirely excluded from contact with the surrounding atmosphere. In the water of rivers containing animal and vegetal matter in a state of decay, are presented all the conditions of life; and hence the numberless forms of the lower organisations which are met with. That these are injurious to health, no one can venture to affirm; but their presence may form, to some extent, an index of the quantity of putrefactive organic matter which may be present. In cases where it is necessary to examine a water microscopically, the following is the plan recommended by the Editor:—

About a quart of the water to be examined should be placed in a conical glass vessel, very narrow at the bottom, in shape something like a tall champagne glass, and covered over with paper. After remaining at rest some hours, a slight deposit will generally be observed at the bottom; and in this deposit will often be seen numerous small animalcula moving about with wonderful rapidity; these have been named by naturalists *Cyclops quadricornis*. They are particularly abundant during the summer in river waters containing much organic matter. Other crustacea are also abundant, amongst which may be mentioned various species of *Daphnia*, which, by their number, often give a marked yellow color to water. Of radiate animals, the hydra and other forms of zoophytes are frequently

present. The fresh water sponge—*Spongia fluviatilis*—frequently occurs in great abundance. Numerous lower forms of the vegetal kingdom often abound in river waters, especially in those of shallow streams. These belong chiefly to families *Confervaceæ*, *Disinidiæ*, *Diatomaceæ*, and *Fungi*. Many of these lower organisms are beautiful objects under the microscope, and well worthy of the attention of all lovers of nature. Space will not allow of any detailed description of the almost numberless species found in water; they have been only briefly alluded to with the view of pointing out the fact, that when they occur in water used for dietetic purposes, they must be regarded as a proof of the presence of dead and decaying organic matter, and must not be looked upon as the only kind of contamination of the water. Their function appears to be to destroy the numerous organic matters which are present. To examine well the deposit formed in the conical glass, the clear water should be siphoned off, and a portion of the deposit placed in the field of the microscope—a quarter-inch glass is perhaps the best for such observations.

Dr. HASSALL examined several specimens of water, both upwards and downwards in the course of the river Thames from London, and they brought to light the singular and important fact that Thames water, from Brentford in one direction to Woolwich in an opposite,

Fig. 613.

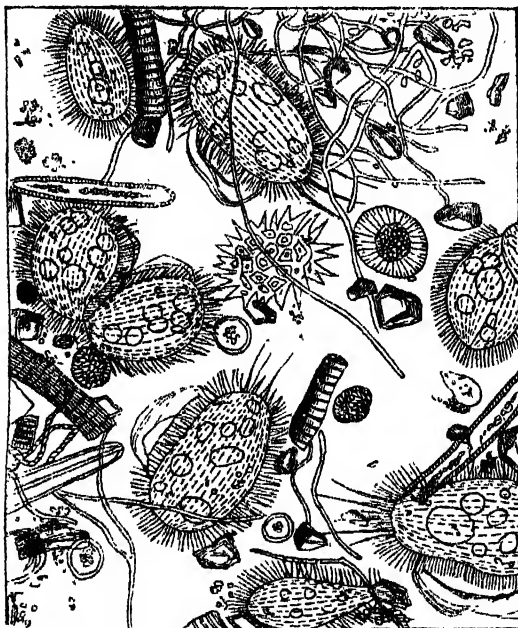


swarms with living productions, principally of the genus *Paramecium*, and of one species of this genus *P. chrysalis* of EHRENBURG.

The engraving exhibits the principal animal and vegetal productions contained in the Thames water at Richmond, drawn with the camera lucida, and magnified two hundred and twenty diameters.

The subjoined cut exhibits the more remarkable vegetal and animal productions found in the water of the Thames at Waterloo Bridge.

Fig. 614.

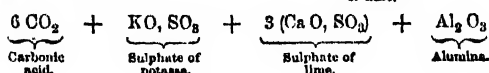
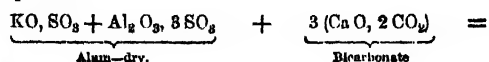


Color of Water.—In rivers the impurity of water is frequently visible to the eye. It is often of a red color, as it flows through rocks of red marl which contain much oxide of iron in their composition. It descends milky from the glaciers of Iceland and the slopes of the Andes, because of the white earth it holds in suspension. It is often grey or brown in the muddiest English rivers. It is always brown when it issues from boggy lakes, or runs across a peaty country, as at Rivington Pike. It is occasionally black to the eye when the amount of vegetal matter is excessive, as in the Rio Negro of South America; and it is green in the geysers of Iceland, in the Swiss lakes, among the islands of the South Sea, and around Great Britain and Ireland. Only in clear and deep water, like those of the Bay of Naples, and in parts of the Pacific, where minute objects may be seen on the bottom some hundreds of feet down, is the real blue color natural to water in large masses distinctly perceptible. This is the deep blue which is seen in the *grotto azzura* of the island of Capri, in the Bay of Naples, and in the deep indigo waters of some parts of the Mediterranean and Adriatic seas.—*Johnston*.

THE ADDITION OF CHEMICAL AGENTS TO WATER.—This head includes several proposed methods of purifying water, which consist in the addition of certain chemical agents to this liquid, by which its composition is altered.

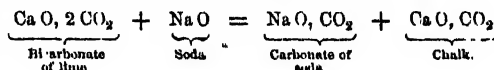
Addition of Alum.—In England, as well as in France, a popular method of clearing muddy water is

to add a few grains of powdered alum to it; two or three grains are usually sufficient for a quart of water. This process is called *alunage de l'eau*; and ARAGO states, that when practised on the Seine water, it causes the mud to agglomerate in long thick striae, which are very quickly deposited. The theory of the process appears to be this:—The alum decomposes the bicarbonate of lime, and gives rise to the formation of sulphate of lime, which, with sulphate of potassa, remains in solution, while carbonic acid is evolved, and hydrate of alumina being precipitated in a flocculent form, carries with it various mechanical impurities.

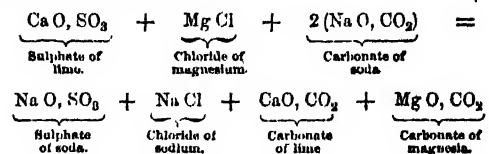


This method, then, is a kind of mechanico-chemical one. It clears the water, but at the same time alters its chemical composition, and by converting bicarbonate into sulphate of lime, augments the hardness of the water.

Addition of Caustic or Carbonated Alkalies.—Caustic alkalies, added to water holding in solution bicarbonate of lime, saturate the excess of carbonic acid, throw down carbonate of lime, and leave an alkaline carbonate in solution. If soda be the alkali used, the results will be as follows:—



If an alkaline carbonate be employed, all the earthy salts—calcareous and magnesian sulphates, chlorides, bicarbonates, and carbonates of the earths—are precipitated, while alkaline sulphates, chlorides, and bicarbonates which do not communicate hardness to water, are left in solution. If carbonate of soda be employed, its reaction on sulphate of lime and chloride of magnesium will be as follows:—



Addition of Lime.—A few years ago, Professor CLARK of Aberdeen took out a patent for the purification of water. His process consists in the addition of caustic lime to water, by which the bicarbonate of lime held in solution is decomposed; the caustic lime saturates the excess of carbonic acid, and forms carbonate of lime, which is precipitated.

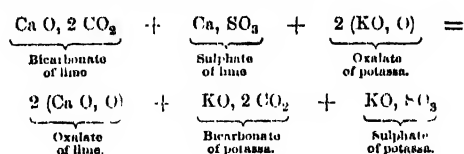


The Editor believes the process of CLARK to be *virtually impracticable on the large scale*, while its efficacy is but slight.

It must be remembered that this mode affects the bicarbonate of lime, not the more troublesome earthy salts, such as the sulphates and chlorides, on which the hardness of spring waters mainly depends. The difficulty of mixing lime and water, in definite proportions, on the large scale, must be obvious to every one. If too much be employed, the companies would supply their customers with *lime-water*! If too little, the bicarbonate of lime would not be completely destroyed, and the process would be a failure. Altogether, the difficulties of carrying out the process will ever prevent its adoption on a large scale.

Addition of Oxalate of Potassa.—Mr. HORSLEY of Cheltenham, some years ago, took out a patent for a new method of preventing incrustations in boilers, and also for depurating, filtering, and otherwise rendering water more fit for drinkable and other purposes. When sea-water is taken for generating steam, he purifies it by employing oxalate of potassa and ammonio-phosphate of soda; and the proportions he uses for the water of the British Channel are about two drachms of oxalate of potassa to about two ounces of the ammonio-phosphate of soda for every gallon. When his object is to februate and soften hard water, he employs such substances as are capable of decomposing the calcareous salts, such as calcined or caustic baryta, or baryta water, phosphate of soda, silicate of potassa, oxalic acid, or the oxalates, and caustic strontia, or strontia water; but he gives the preference to oxalate of potassa. He first ascertains the degree of hardness of the water, and then adds the requisite quantity of oxalate of potassa, by which an oxalate of lime is precipitated; and there remains in solution, instead of the lime thus displaced, a carbonate, sulphate of potassa, or chloride of potassium, as the case may be, and the water is purified and fit for use.

The following equation explains the reaction of oxalate of potassa; the salt is assumed to be neutral on bicarbonate and sulphate of lime:—

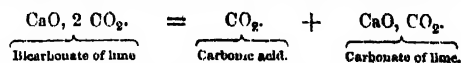


HORSLEY's patent process does that which CLARK's fails to do: it decomposes all the earthy salts on which the hardness of water usually and mainly depends. But it is open to still greater objections than those that have been raised to the other method. Besides being, like CLARK's, process virtually impracticable, it would prove very expensive, and as regards the metropolitan river-waters, it is quite unnecessary. Moreover, the idea of *physicking* or *doctoring* water, by the addition to it of a poisonous agent, would, if even no other objection existed to this scheme, be quite fatal to it. For though, in the hands of competent persons like Mr. HORSLEY, no possible injury could arise from its use; yet the public would always have some suspicion of water thus treated; and, as a celebrated English engineer observed to ARAGO, water, like *Cæsar's wine*, should be above suspicion, which the Rivington Pike

water supplied to Liverpool is not. Liverpool was formerly supplied with spring water from the red sandstone, beautifully cool and refreshing, and free from organic matter. Now the inhabitants are forced by a stubborn water committee to drink a mixture of the rock and surface water—how the people suffer it is to the Editor a mystery—the latter certainly *blasting its wholesome brother*. The small town of Flint, North Wales, has infinitely better water than is supplied to any of the principal towns of England.

Purification and Filtration of Water.—JOHNSTON says truly, that the water used by a nation or country is an important matter in a well-considered and long-adjusted diet. It by no means follows in all cases, perhaps not even in the majority, that the *purest* water—see *Distilled Water*—is the best for the health of a given family, or for the population of a given district. The bright, sparkling, hard waters which gush out in frequent springs from the chalk and other limestone rocks are relished to drink, not merely because they are grateful to the eye, but because there is something exhilarating in the excess of carbonic acid they contain and give off as they pass through the warm mouth and throat, and because the lime they hold in solution neutralizes or counteracts acid matters in the stomach, and thus acts as a grateful medicine to the system.

On entering upon the purification and filtration of water, it may be stated as an axiom that *the best filter is no substitute for bad water*; still, as various towns throughout the kingdom are supplied with bad water, that is, water containing chemical and mechanical impurities, the Editor deems it necessary to explain to the reader how to remove these wholly or in part, so as to *better* the water. The depuration of water is greatly aided by repose, by which various suspended or mechanical impurities are allowed to subside gradually, and from these the supernatant fluid is drawn or siphoned off. Tanks, cisterns, and reservoirs become therefore important depurating agents. The purification of water by subsidence and decantation is the simplest of all methods of februation; but unfortunately it is a very slow one. It is stated that the water of the Garonne, taken when the river is swollen, does not regain its natural limpidity after a fortnight of perfect rest. The larger particles, of course, quickly deposit, but the finer ones precipitate very tardily. During the time that deposition is occurring, the water is exposed to the air, and consequently undergoes a chemical metamorphosis. The bicarbonate of lime which is dissolved in it parts with a portion of its carbonic acid, and carbonate of lime precipitates:—



In this way the atmosphere assists in softening those waters, which owe the whole or a portion of their hardness to the above calcareous salt. The atmosphere, however, is a source of contamination as well as of purification, and it is on this account that the Editor always condemns the use of *surface* water for dietetic purposes. EHRENBURG states that, exclusive of inorganic substances, he has detected three hundred and twenty species of organic forms in the dust of the

winds. It is obvious, therefore, that waters which are chemically very pure, must become contaminated by exposure in deposit reservoirs.

What are the best methods of purifying water on a large scale?

The water, says TOMLINSON, used for culinary, domestic, and industrial purposes, is exclusively derived from the rain which falls upon the earth, whether the immediate source of supply be the cistern, the well, the spring, or the river. Rain-water is usually so pure, that the action of the most delicate chemical tests is required to detect any foreign substance in it; so that, if cisterns were formed of proper materials, and the rain fell directly into them in sufficient quantity, no better water could be desired. But as the exposed surface of cisterns is too small to collect rain-water in any quantity, it is usual to discharge into them, by means of gutters and shoots, the water which falls upon the roofs of houses; and, as these are covered with dust, insects, and other impurities collected during dry weather, the rain-water of cisterns is thus contaminated in various ways. In some places the rain-water, collected on the surfaces of extensive roofs and flats, is made to pass through a bed of porous materials on its way to the cistern, and thus the solid impurities are strained and separated before the water is used by the public. Such is the case with the large cistern of the ducal palace at Venice.*

Wells may be compared with cisterns; but the channels which discharge rain-water into them are not formed of masonry, brick, or metal, but of the rocks which exist immediately beneath the surface. These rocks may be porous, or may abound in minute fissures, through which the rain-water, sinking through the soil, finds a passage; and being divided into innumerable liquid threads, it dissolves and carries along with it a portion of whatever soluble matter it may encounter. Hence, the water obtained from wells is not rain-water, properly so called; it is usually as clear and limpid, but it contains nearly always certain substances in solution, which vary according as the geological structure of the country differs. The same remark applies to springs: their water is rain-water, which, after having traversed strata of greater or less thickness, is sent up to the surface by the pressure of the water in the neighboring hills or other elevations. The nature and proportion of the impregnation to which spring-water is subjected, depend also on the extent of its transit and the kind of rock traversed. The action of rain-water upon certain kinds of rock leads to the production of mineral springs; and if the water descends to a certain depth in the earth, its temperature will be so much raised by the internal heat, that on reappearing at the surface, it will be as a thermal spring.

In filtering on a large scale, for the supply of a city, for example, the cost and durability of the filter are important considerations. On the great scale of Nature, the rocks which filter the water, as it falls upon the surface of the soil, constitute a vast permanent filter, the durability of which arises from the great extent of superficial or subterranean surface concerned. It might at first view appear to be easy to imitate this natural operation, and pass the muddy water of a river through

the porous rock or sand which forms its banks; but this is often an expensive proceeding, on account of want of permanence of an artificial structure so contrived. Toulouse is supplied with water from the Garonne in this way, and it has cost upwards of forty thousand pounds at various times for supplying a city of only fifty thousand inhabitants. The cause of failure in this and other instances arises from the fact already noticed, that when water percolates sand, it deposits its solid impurities to a certain depth between the interstices of the filtering medium, rendering it necessary from time to time to renew the sand. This is illustrated by some experiments conducted by Mr. WICKSTED. A sand filter which yielded at the rate of ten the first week, yielded nine the second week, six the third week, and only two the fourth week; so that a large natural filter—as this description of filter is called—may go on for some years, yielding a good supply of water, and then gradually diminish it until it ceases altogether. Hence the construction of these so-called natural filters requires much caution on the part of the engineer; and it will always be difficult, if not impossible, to calculate before hand the amount of water which a natural filter proposed to be erected will yield.

A second system of filtration on a large scale consists in the formation of extensive beds of sand of great thickness, resting on beds of gravel, *et cetera*. At intervals of time, from ten to fourteen days, the water is run off; and the filth which had accumulated during filtration is scraped off with a certain thickness of the sand of the filtering bed. Once or twice a year the whole of the sand removed is replaced. This method is costly, and not altogether satisfactory.

Of all the permeable substances used for filtration, animal charcoal possesses in the highest degree the combined mechanical and chemical influence. In addition to its power, in common with other filtering media, of removing suspended or mechanical impurities, it also abstracts from the liquid which percolates it, various *dissolved* bodies, and thus effects a metamorphosis in the chemical composition of the fluid which traverses it. These important properties of animal charcoal have oftentimes led to its use as a filtering medium for water; and hence it is introduced into many of the ordinary domestic water filters. But its deodorizing and decoloring power is soon lost; and, in order to enable it to reacquire its original efficacy, it requires to be re-formed.

There can be no doubt that of all known permeable bodies, the only ones which present all the requisites of filtering media for water on a large scale, are sand and gravel. They are cheap, allow the rapid passage of water through them, and, when *they have been previously well washed*, communicate no taint to the waters which traverse them. Their employment must have been suggested to man by the observation of the numerous limpid springs which are seen in arenaceous districts.

Their action, however, is chiefly *if not entirely* mechanical. They possess little or none of that power of effecting chemical changes on the liquids filtering through them, which animal charcoal possesses in so pre-eminent a degree. Yet, unless several distin-

guished writers have grossly deceived themselves, sand is not entirely devoid of this chemical influence. WAGENMANN, for example, found that when vinegar was filtered through pure quartz sand, the first portion of liquid that percolated was deprived of almost *all its acid*; and the vinegar did not pass through unchanged until the sand had become well charged with acid. The same authority also states that potato-brandy diluted with water, and filtered through quartz-sand, yields at first pure water, then a mixture of water and alcohol deprived of its fusel-oil; and, lastly, the original mixture unaltered. BERZELIUS filtered a saline solution through a long tube filled with sand, and found that it ran out more or less completely deprived of salt. MATTEUCCI repeated BERZELIUS' experiment, and confirmed his statement. He filled a tube about twenty-six feet long with sand, and filtered a saline solution through it; and he found that the density of the liquid introduced by the upper aperture of the tube was to that of the liquid escaping from the lower end, as 1.00 to 0.91. But he observed that this difference of density was not always maintained; for, after a certain time, the saline solution becomes as dense at its exit from, as at its entrance into the tube, proving that the decomposition of the saline solution takes place in the first action of contact between it and the particles of sand. But a still more remarkable result, the inverse of the one just stated, was obtained by the last-mentioned chemist, with a solution of carbonate of soda. He filled a tube nearly ten feet long with sand, and filtered a solution of carbonate of soda through it; and he found that the density of the liquid at its entrance was to that at its exit as 1.000 to 1.005. In this case, then, the sand had deprived the solution of part of its water, and had thereby increased the gravity of the liquid which percolated. Assuming, however, the accuracy of all these reported observations, it cannot be doubted that, *in a practical point of view*, the efficacy of sand, as a filtering medium, depends on its *mechanical, not on its chemical influence*.

Domestic Filters.—In coming now to notice small filters for domestic purposes, such a multitude of inventions and contrivances start up to view that, as TOMLINSON says, how to choose and where to begin is difficult. There are certain classes of subjects, says the same authority, on which the genius of inventors seems to run riot. *Filters* form one of these, and *fire-escapes* another. In either class examples are as numerous as the attempts to solve the problem of perpetual motion, or to square the circle. Almost every kind of porous substance has been enlisted into the service of filters. The animal, vegetal, and the mineral kingdoms have each contributed. Charcoal—animal and vegetal—sponge, flannel, cotton, straw, hemp, saw-dust, wood shavings, branches and leaves, various kinds of porous stone, sand, pounded glass, zinc and iron filings, are a few only of the materials that have been recommended or used; and the methods of employing them are as various and as dissimilar as the substances themselves. The Editor considers the best filter for home use to be that of FORSTER of Liverpool, which he employs in his own house. The water percolates a fine porous stone, which removes all mechanical impurities, and

imparts a freshness to the water, which is not the case when sponge, charcoal, and other substances are the filtering media. It is, as TOMLINSON states, remarkable that very few filters were exhibited in the foreign department of the Great Exhibition. France sent three—two of stone and one of charcoal. An ingenious form of filter was exhibited by the Wenham Lake Ice Company, which consisted of a siphon, the extremity of the short limb of which is furnished with a box containing the filter, so that on inserting this into a cistern or cask holding water, and applying suction at the extremity of the longer limb, a stream of filtered water can be obtained, which may be arrested or drawn at will by shutting or opening the tap, as seen in the figure. In the laboratory, unsized paper is almost exclusively employed as a filtering medium. Other substances, such as flannel, tow, sand, pulverized glass, may occasionally be used.

An arrangement is also made for retaining the liquor in the filter at the same height, until the whole of the fluid to be percolated is expended. To insure this, the menstruum to be passed through is held in a flask inverted, the neck of which, as the reader will perceive by the wood-cut, dips into the liquor already contained in the funnel. As the liquor descends, and the neck of the flask becomes uncovered, a bubble or two of air enters; more liquor exudes, until the neck becomes again immersed, and all communication with the air is again cut off.

VESSELS FOR CONTAINING WATER.—Lead and other metals are very useful to store water in. The Editor is very glad to find, however, that the clean, inexpensive, and beautiful material, slate, is coming into use for cisterns, instead of lead, which is a dangerous metal to have in contact with a liquid of such daily and universal consumption.

DISTILLED WATER.—Certain technical and analytical purposes demand that the water employed by the operator or analyst be perfectly pure. To insure this, distillation is resorted to, by which operation the foreign matters held in suspension or solution are separated. Dr. NORMANDY remarks, that the distillation should be arrested when the salts begin to precipitate; for if the process were continued, part of these saline matters might suffer decomposition, and thus contaminate the distillate. The annexed table from NORMANDY shows the characteristics of pure water. It must not become turbid, or produce a precipitate with any of the subjoined reagents:—

Baryta water—If a precipitate or opaqueness appear, carbonic acid is present.

Chloride of barium—Shows sulphates.

Nitrate of silver—Indicates chlorides.

Oxalate of ammonia—Evidences lime salts.*

Sulphide of hydrogen, solution made slightly acid—Antimony, arsenic, tin, copper, gold, platinum, mercury, silver, lead, bismuth, cadmium.

Sulphide of ammonium, solution alkalinized by ammonia—Nickel, cobalt, manganese, iron, zinc, alumina, chromium.

Chloride of mercury, chloride of gold, sulphate of zinc—Prove organic matter.

Pure distilled water, evaporated on a piece of platinum foil, *should leave no residue*. As a drink it is insipid, and is not recommended except in some cases of calculi.

The following table, embracing the composition of some principal river and well waters, will prove interesting to the reader:—

GRAINS IN THE IMPERIAL GALLON.

	RIVER.								WELL.	
	Clyde, Glasgow, Penny.	Leven Penny.	Stee, Dewlie.	Rhine, Dewlie.	Garonne, Dewlie.	Loire, Dewlie.	Rhone, Dewlie.	Doubs, Dewlie.	Arceuil Aquaduct, at Paris.	Dijon.
Carbonate of lime,.....	2.52	.50	11.609	9.511	4.524	3.374	5.934	13.397	12.958	16.133
Sulphate of lime,.....	.26	.52	1.886	1.030	—	—	—	—	11.490	—
Chloride of calcium,.....	—	—	—	—	—	—	—	—	—	—
Carbonate of magnesia,....	.72	—	.189	.350	.238	.427	3.430	.161	.575	.266
Sulphate of magnesia,....	—	—	trace	—	—	—	—	—	—	—
Chloride of magnesium,....	.40	.63	—	—	—	—	—	.035	1.163	—
Sulphate of soda,.....	1.94	.39	—	.945	.371	.238	.519	.357	.378	.189
Carbonate of soda,.....	—	—	—	—	.455	1.023	—	—	—	.147
Chloride of sodium,.....	.54	.73	.862	.140	.224	.336	.119	.161	2.637	.224
Sulphate of potassa,.....	1.94	.39	.350	—	.533	—	—	—	1.410	—
Nitrate of potassa,.....	—	—	—	2.560	—	—	.280	.287	—	.189
Nitrate of soda,.....	—	—	.659	—	—	—	.315	.273	—	—
Nitrate of magnesia,.....	—	—	.364	—	—	—	—	—	3.998	—
Phosphates—earthy,.....	.31	.18	—	—	—	—	.333	—	—	—
Alumina,.....	.28	.32	.045	.175	—	.498	—	.147	.371	.070
Oxide of iron,.....	trace	—	.175	.406	.217	.385	—	.210	—	—
Silicic acid,.....	.28	.32	1.711	3.423	2.813	2.818	1.669	1.111	2.146	1.068
Organic matter,.....	.89	.45	—	—	—	—	—	—	—	—
	7.86	3.75	17.840	16.247	9.585	9.437	9.082	16.142	37.126	18.283

Physiological Effects.—Water is an essential part of the blood and of the living tissues. It is from this liquid that the tissues derive their properties of extensibility and flexibility. It gives fluidity to the blood, and enables the transportation of organic particles from one part of the body to another to be effected. Lastly, it contributes to most of the transformations which occur within the body. Considered dietetically, aqueous drinks serve several important purposes in the animal economy: they repair the loss of the watery part of the blood, caused by evaporation and the action of the secreting and exhaling organs, and thereby assist the stomach in the act of digestion. If, however, they are swallowed in excessive quantity, they may impede digestion by diluting the gastric juice. It is not improbable that water acts as a real nutritive agent, that is, assists in the formation of the solid parts of the body. As an agent for the communication or abstraction of heat to or from the body, water has been before noticed. Furthermore, the influence of atmospheric humidity modifies the character of climates.

Water moderately warm, and which neither cools nor heats the body, acts locally as an emollient, softening and relaxing the various tissues to which it is applied. When swallowed, it allays thirst, becomes absorbed, mixes with and thereby attenuates the blood, and promotes exhalation and secretion, especially of the aqueous fluids. Administered in large quantities, it excites vomiting. The continued excessive employment of water has an enfeebling effect on the system, both by the relaxing influence on the alimentary canal, and by the excessive secretion which it gives rise to. Injected into the veins in moderate quantities, tepid water has no injurious effects; it quickens the pulse and respiration, and increases secretion and exhalation. Large quantities check absorption, and cause difficulty of breathing and an apoplectic

condition. Thrown with force into the carotid artery, it kills by its mechanical effects on the brain.

Besides the dietical and thermotic purposes for which water is employed in medicine, it serves as a diluent, humectant, emollient, evacuant, and, in pharmacy, as a solvent. Water, or bland aqueous fluids, are employed in some cases of poisoning. They serve to dilute the acrid and irritant poisons, the intensity of the action of which on the stomach they lower. Moreover, the presence of aqueous fluids favors the expulsion of substances by vomiting. In preternatural dryness and rigidity of parts—for example, of mucous surfaces, the skin, wounds, and ulcers—water and mild aqueous fluids are useful moisteners and emollients. The copious use of water augments the quantity of fluid thrown out of the system by the cutaneous and pulmonary surfaces, and by the kidneys. If the object be to promote diaphoresis, external warmth should be conjoined with the internal use of diluents; whereas, when one wishes to excite the renal vessels, the skin should be kept cool. In inflammatory affections of the urinary passages, the free employment of aqueous fluids is advised, with the view of diluting the urine, and thereby of rendering it less acrid and irritating. What is called water-dressing may be regarded as a modified and improved form of poultice. It consists in the application of two or three layers of soft lint dipped in water, and applied to inflamed parts, wounds, and ulcers, the whole being covered with oil silk or Indian rubber, which should project beyond the margin of the lint to retain the moisture, and prevent evaporation. Dr. MACARTNEY considers it to operate differently to a poultice; unlike the latter, he says, it prevents or diminishes the secretion of pus, checks the formation of exuberant granulations, and removes all pain. Moreover, the water is not liable to become sour like a poultice, and does not injure the sound part. Water

is frequently employed in pharmacy for extracting the active principles of various medicinal agents.—*Pereira*.

MINERAL AND OTHER WATERS.—*GLOVER* justly remarks that few subjects connected with medicine are more interesting to the general reader than that of mineral waters. The circumstances attending their administration, the natural mode of their production, the scenery in which they are often placed, and the associations frequently surrounding them, combine to give them, as remedies, an interest exceeding that of ordinary medicinal agents. Hygiene and medicine, in the narrow acceptation of the terms, join hand in hand at the salubrious fountain. Spas have been exalted, and are still exalted by interested parties, as panacean cures for all diseases; others unworthily decried; source has been pitted against source, and pump against pump; and battles fought between biassed spa-doctors, which only tended to raise doubts in the opinions of thinking men.

To enter largely into the subject of natural and artificial mineral waters would be quite out of place in a book of this description, and it would be incompatible with the assigned limits to give more than a general insight into their nature, character, composition, and manufacture. The great *furor* for saline and other springs is daily abating; a very striking proof of this being evidenced at Cheltenham, to which thousands used to rush yearly to partake of its waters, whereas now it is almost entirely deserted. The same, no doubt, will soon be the case with other places, and artificial will, in many cases, supply the place of natural waters. Is not more due to the diet, change of scene and air, than to the virtues said to be possessed by certain springs? What miraculous cures are stated to have been produced by the water of Holywell, Flintshire, North Wales; and yet analysis reveals *nothing* particular in this spring to impart to it medicinal properties, as illustrated by the annexed tabulated results of Mr. JAMES BARRATT, pupil of the Editor—

Temperature,.....	52°
Specific gravity,.....	1.0015
	Grains.
	Per Imperial gallon.
Carbonate of iron,.....	traces
" lime,.....	13.685
" magnesia,.....	2.688
" soda,.....	1.432
Chloride of calcium,.....	3.094
" potassium,.....	traces
" sodium,.....	0.821
Silicic acid,.....	2.737
Sulphate of lime,.....	5.202
" magnesia,.....	traces
Total,.....	29.659

Direct determination of fixed constituents, 30.450

Free carbonic acid, 10.338 grains, = 21.874 cubic inches.

This famous spring is the first in Great Britain; it never freezes, and scarcely varies in the quantity of water it emits, drought or wet weather, flinging out *twenty-one tons a minute*.

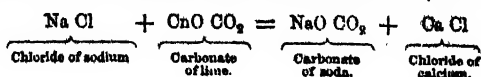
PEREIRA remarks—Mineral waters were known to mankind in the most remote periods of antiquity, and were employed medicinally both externally and internally. *HOMER* speaks of tepid and frigid springs. The *Æsculapidae*, or followers of *ÆSCULAPIUS*, accord-

ing to *SPRENGEL*, erected their temples in the vicinity of mineral and thermal waters. *HIPPOCRATES* mentions mineral waters, although he does not prescribe them when speaking of particular diseases. Their medicinal properties are spoken of by *PLINY*.

The principal source of saline waters is the rain, snow, hail, dew, percolating a certain portion of the soil, and dissolving various matters in their passage, so as to reappear on the surface at the bottom of declivities as spring-water; or when procured by sinking pits or wells—well-water. But springs are sometimes observed, continues *PEREIRA*, under circumstances which are inconsistent with the supposition of their atmospheric origin. The boiling springs, says *GAIRDNER*, which emerge on the verge of perpetual snows at an altitude of thirteen thousand feet above the level of the sea, as in the Himalayas, cannot be derived from the air.

Mineral waters, of course, procure their particular and distinctive properties or qualities from the strata through which they flow. Those of the primitive formation are almost all thermal, generally possessing a high temperature, while those of the older secondary formations are generally cooler. The hot or thermal waters are those possessing a degree of heat more or less raised above the mean of the latitude or elevation at which they are found, and the changes of which, if any, observe no regular periods coincident with the revolutions of the seasons. Three causes, says *PEREIRA*, have been assigned as the source of the temperature of mineral waters, namely, volcanic action, now in existence; volcanic, now extinguished, but the effects of which still remain; and a central cause of heat, which increases in descending from the surface to the interior of the earth. The *Geysers*, or boiling springs of Iceland, are evidently the result of volcanic action.

PEREIRA proceeds—The origin of the saline and other constituents of mineral waters is another interesting topic of inquiry connected with the natural history of mineral springs. As water, in its passage through the different strata of the globe, must come in contact with various substances which are soluble in it, one refers certain constituents of mineral waters to solution and lixiviation merely, as chloride of sodium, carbonates of lime and magnesia, oxides and bromides of sodium and magnesia, iron, silicic acid, *et cetera*. Chemical action must, in some cases, be the source of other constituents. Sulphide of hydrogen is most likely the result of the action of water on some metallic sulphide, especially iron pyrites; sulphurous or sulphuric acid from the oxidation and combustion of sulphur, free or combined. In acidulous or carbonated waters the carbonic acid probably arises from the decomposition of chalk either by heat or sulphuric acid. The disintegration of chlorides of sodium or ammonium would eliminate hydrochloric acid, while carbonate of soda, found so largely in the native lakes of Egypt, might, as *BERTHOLLET* supposes, be proved by the action of chloride of sodium or carbonate of lime; thus—



GAIRDNER states that the different orifices of the Karlsbad Sprudel discharge annually about thirteen thousand tons of carbonate of soda and twenty thousand tons of sulphate of soda, in a crystallized state; and further adds, that a very simple calculation is sufficient to prove that the Donnersberg alone, the highest of the Bohemian Mittelgebirge, a cone of clinkstone two thousand five hundred feet in elevation, eviscerates soda sufficient to supply the Karlsbad waters for more than thirty thousand years.

The Editor agrees with PEREIRA that the best classification to adopt is that of grouping mineral waters into four classes, *vide licet*, chalybeate, sulphurous, acidulous, and saline.

CHALYBEATE OR FERRUGINOUS WATERS.—These terms are applicable to those waters, the active principle of which is *iron* in considerable quantity. These waters possess a styptic taste, and when they contain the protoxide of the metal, yield, with ferrocyanide of potassium, a *white* or bluish-white precipitate; and if the sesquioxide be present, they give a *blue* precipitate with ferrocyanide of potassium, and become *red* with

the alkaline sulphocyanide. The carbonated chalybeates are of two kinds, those containing the carbonate of iron, associated with much carbonic acid, which renders them acidulous and effervescent. The Pyrmont, Trinkwelle or drinking spring, Schwalbach Spa, and Pouchon, are of this nature.

The noneffervescent ones are Oddy's saline chalybeate at Harrowgate, the Islington Spa near London, and the waters of Tunbridge Wells. These are also sulphated chalybeates, but they are not of so much importance.

SULPHUROUS OR HEPATIC WATERS.—The most celebrated of these waters are—in England, those of Harrowgate, the appended analyses by Dr. A. W. HOFFMANN being given; Scotland—Moffat and Rothesay; of the Continent—Enghien, Barèges, Aix, near Geneva, Aix-la-Chapelle, and Baden. They have the disagreeable smell of rotten eggs, and give, with salts of lead, bismuth, copper, *et cetera*, black precipitates.

Subjoined are analyses by Dr. HOFFMANN of several of the most important saline chalybeates at Harrowgate:—

GRAINS OF SALINE CONSTITUENTS IN THE GALLON OF WATER.

	Old sulphur well	Montpellier strong sulphur well.	Montpellier mild sulphur well	Hospital strong sulphur spring	Hospital mild sulphur spring	Starbeck sulphur spa.
Temperature,	48.2°	46.4°	42.8°	41.9°	44.6°	48.2°
Specific gravity,	1.01113	1.01045	1.00314	1.00515	1.0026	1.0018
Ammonia,	trace	trace	trace	trace	trace	trace
Bromide of sodium,	trace	—	trace	trace	trace	trace
Carbonate of iron,	trace	trace	trace	1.060	trace	trace
“ lime,	12.365	24.182	20.457	25.560	19.704	6.960
“ magnesia,	—	—	3.251	5.797	—	—
“ manganese,	trace	trace	trace	trace	trace	trace
“ potassa,	—	—	—	—	—	12.207
“ soda,	—	—	—	—	—	5.133
Chloride of calcium,	81.735	61.910	—	—	—	—
“ magnesium,	55.693	54.667	17.140	11.595	0.336	—
“ potassium,	64.701	5.750	3.975	10.751	24.970	—
“ sodium,	866.180	803.093	232.413	369.014	220.630	121.798
Fluoride of calcium,	trace	trace	trace	trace	—	faint trace
Iodide of sodium,	trace	—	trace	trace	trace	trace
Organic matter,	trace	trace	trace	1.327	trace	1.740
Silica,	0.246	1.840	0.165	0.535	1.40	1.753
Sulphate of lime,	0.182	0.594	12.104	51.660	1.215	0.870
Sulphide of sodium,	15.479	14.414	3.398	7.155	0.301	1.711
Total,	1096.581	966.450	292.903	484.454	279.046	157.562

GASES DISSOLVED BY THE WATERS AND EXPELLED BY EBULLITION IN VACUO.

Composition in one hundred volumes.

	Old sulphur well.	Montpellier strong sulphur well.	Montpellier mild sulphur well	Hospital strong sulphur spring.	Hospital mild sulphur spring.	Starbeck sulphur spa.
Carbonic acid,	61.06	70.62	62.50	31.79	44.07	49.78
Carbide of hydrogen,	16.17	2.71	3.99	0.52	22.80	27.71
Nitrogen,	8.08	24.21	33.51	65.88	25.31	22.51
Oxygen,	—	2.46	—	—	7.82	—
Sulphide of hydrogen,	14.69	—	—	1.81	—	trace
Total,	100.00	100.00	100.00	100.00	100.00	100.00

CUBIC INCHES OF THE GASES IN THE GALLON OF WATER.

	Old sulphur well.	Montpellier strong sulphur well.	Montpellier mild sulphur well	Hospital strong sulphur spring.	Hospital mild sulphur spring.	Starbeck sulphur spa.
Carbonic acid,	22.03	14.01	14.28	9.54	10.20	9.26
Carbide of hydrogen,	5.84	0.53	0.90	0.15	5.28	5.15
Nitrogen,	2.91	4.82	7.67	19.78	5.87	4.21
Oxygen,	—	0.48	—	—	1.81	—
Sulphide of hydrogen,	5.31	—	—	0.54	—	trace
Total,	36.09	19.84	22.85	30.01	23.16	18.62

COMPOSITION OF THE GASES, IN ONE HUNDRED VOLUMES, RISING FROM THE WATER IN BOURBON.

	Old sulphur well	Hospital strong sulphur spring
Carbonic acid,.....	3.28	0.09
Carbide of hydrogen,.....	40.00	—
Nitrogen,.....	56.72	99.91
Oxygen,.....	—	—
Sulphide of hydrogen,.....	trace	trace
Total,.....	100.00	100.00

The sulphide of hydrogen exists in the above waters, partly free and partly combined. Only a portion can be expelled by ebullition. The amount of the sulphide of hydrogen in the waters varies, which may be partly due to influences affecting the strata through which the waters ascend; to a great extent, however, they must be ascribed to the action of the air.

The general operation of these waters, says PEREIRA, is stimulant. They are adapted for chronic complaints, and are supposed to possess a specific power over the cutaneous and uterine systems, and are said to be beneficial in chronic rheumatism and gout. As previously remarked, would not an iron salt, judiciously administered, act just as well in the above-mentioned diseases?

ACIDULOUS OR CARBONATED WATERS.—The name here implies waters charged with carbonic acid. Most waters contain a few cubic inches of carbonic acid in the gallon, but the acidulous will eviscerate from thirty to two hundred cubic inches. It is stated by ALIBERT that the waters of Saint Nectaire hold four hundred cubic inches in one hundred of the water.

Carbonate or bicarbonate is contained in waters of this kind, and, when this is the case they are called *acidulo-alkaline*. The Selters, Altwasser, Salzbrunn, Reinerz, and Pyrmont acidulous waters are of this description. Protocarbonate of iron is sometimes present in them, classifying them under *acidulous carbonated chalybeates*. The spring at Ilkeston, near Nottingham, is the only water of the above class in Great Britain.

Acidulous waters are cooling, refreshing, and exhilarating, and oftentimes relieve nausea. The acidulo-alkaline waters are useful in the lithic acid diathesis, in gout and rheumatism, *et cetera*.

SALINE WATERS, according to PEREIRA, may be divided into five kinds:—

Purging Saline Waters.—Sulphates of soda or magnesia are the active ingredients of these waters: some owe their efficacy to sulphate of magnesia, others to sulphate of soda.

Bitter Purging Waters, Bitter Waters, Bitter-Salt Waters.—Sulphate of magnesia predominates in these waters. Epsom and Scarborough in England, and Seidlitz, Seidchütz, and Püllna on the Continent, are of this kind. Some thermal springs, as those of *Acqua del Pozzeto*, near Pisa, contain sulphate of magnesia.

Glauber Salt Waters.—Some writers give this name to those waters holding sulphate of soda in solution. Some of these are warm, and on this account are called the *warm alkaline glauher salt waters*. To this division belong the famous springs of Carlsbad,

now so much resorted to for good—or evil! Further on analyses are given of the Carlsbad water, and of several others of the leading and well-known Continental springs. Some of this class of waters are devoid of alkaline properties, but contain, besides sulphate of soda, various earthy and alkaline salts. They are the *earthy glauher salt waters*. To this division belong the deserted springs of Cheltenham, and those of Leamington and Spital.

In large doses the waters of this kind are mild cathartics. PEREIRA says they are useful in diseased liver, dropsical diseases, *et cetera*.

Salt or Brine Waters.—The characteristic ingredient of these springs is chloride of sodium. Iodine or bromine, or both, have been found in some of them, and these most likely add to their medicinal effects. The small quantity of iodine recently found in the water of St. Ann's Well at Great Malvern, Worcestershire, by the Editor, is doubtless the active ingredient in that water.

The Kreuznach and Salzhausen springs in Germany are among the brine springs, and in England the principal ones are at Middlewich and Nantwich in Cheshire, Shirleywich in Staffordshire, and Droitwich in Worcestershire.

Taken in large quantities, saline or brine springs are emetic and purgative. They have been principally celebrated in glandular swellings. The water of Baden Baden contains a large quantity of chloride of sodium.

Analysis of the water of Baden Baden by the Editor:—

	Imperial gallon. (176 lbs.)
Alumina,.....	trace
Carbonate of iron,.....	1.356
“ lime,.....	14.184
Chloride of calcium,.....	11.040
“ potassium,.....	13.720
“ sodium,.....	132.644
Organic matter,.....	trace
Phosphate of lime,.....	trace
Silicic acid,.....	2.947
Sulphate of magnesia,.....	5.236
	181.127

Specific gravity,.....	1.00284
Carbonic acid,.....	4.5 cubic inches.
Sulphide of hydrogen,.....	trace.

Calcareous Waters.—These saline mineral waters, the leading constituent of which is either the sulphate or carbonate of lime, belong to this order.

The Buxton, Bath, and Bristol thermal waters, come under the same category. Annexed is an analysis of the Buxton water just completed by the Editor; it differs materially from the one made by his friend PLAYFAIR some time ago, except in the amount of gases:—

	Grains in the Imperial gallon.
Carbonate of lime,.....	8.541
Carbonate of magnesia,.....	3.741
Carbonate of protoxide of iron,.....	0.082
Sulphate of lime,.....	0.330
Chloride of calcium,.....	1.227
Chloride of magnesium,.....	0.463
Chloride of sodium,.....	2.405
Chloride of potassium,.....	0.260
Silica,.....	1.044
Nitric acid,.....	trace
Organic matter,.....	0.341
Fluoride of calcium,.....	} trace
Phosphate of lime,.....	
Total per gallon,.....	18.434
Free carbonic acid,.....	3.5 cubic inches.
Nitrogen,.....	504 "

Calcareous waters are stimulant, alterative, and constipatory. Externally they are said to be beneficial in the cure of rheumatism, gout, chlorosis, chronic skin diseases, *et cetera*.

The quantity of nitrogen gas accompanying this water has been previously alluded to. Dr. ROBERTSON, in treating of the physical characters of the Buxton waters, ascribes their brilliancy when drawn to the quantity of gas held in solution. Of course, this must be fallacious, for very little gas is held in solution or dissolved. As GLOVER remarks, what occurs in the baths, where a quantity of the nitrogen has been forced along by the current of water, three hundred gallons per minute, furnishes no indication of the amount of gas in solution. The great use of the Buxton water is, of course, externally, but upon what its effects mainly depend still remains unexplained.

Mr. J. ARMITAGE PEARSON, the eminent consulting surgeon of Buxton, has informed the Editor that he does not look upon the nitrogen in any water to be an effective element; and although one sees the gas constantly gurgling forth in strong streams, still Mr. PEARSON agrees with the Editor, that being an insoluble gas, it is not absorbed into the system; and even supposing that it could be absorbed, it could not exert any beneficial result. All water is a diuretic, more or less. Mr. PEARSON places very little value on the Buxton waters *per se*; but administered with a certain and most valuable medicine—an alkaloid—which he has prescribed, he has effected several wonderful cures. The lime salts in the water no doubt exert a beneficial influence.

To divert the reader's attention a little, the following anecdote with regard to how waters of one kind or another become celebrated, is given by the writer of *Bubbles from the Brunnens of Nassau*, with regard to the discovery of the far-famed waters of Slangenbad. It is characteristic of the supposed origin of many similar watering-places, and as such it may amuse, if it does not much edify, the reader:—In the history of the little Duchy of Nassau, says that graceful writer, the discovery of the spring forms a story full of innocence and simplicity. Once upon a time, there was a heifer with which everything in nature seemed to disagree. The more she ate, the thinner she got. The more her mother licked it, the thicker and more staring was her coat. Not a fly in the forest would bite her. Never was she seen to chew the cud; but, hide-bound and

melancholy, her hips seemed to be actually protruding through her skin. What was the matter with her no one knew; what could cure her, no one could divine; in short, neglected by her master and her species, she was, as the faculty would term it, *given over*. In a few weeks, however, she suddenly reappeared among the herd with ribs covered with fat, eyes like a deer, skin as sleek as a mole, breath smelling sweetly of milk, saliva hanging in ringlets from her jaw. Every day seemed to re-establish her health, and the phenomenon was so striking, that the herdsman, having watched her, discovered that regularly every morning she wound her way in secret into the forest, until she reached an unknown spring of water, from which, having refreshed herself, she quietly returned into the valley. A young Nassau lady showed symptoms similar to those of the heifer, and the herdsman recommended the water, which cured her!

GLOVER says justly in his very readable work on mineral waters, that there is a certain mystery connected with the origin and mode of operation of some of them, which no doubt with many is attractive, just as in the extraordinary doctrines of HAHNEMANN and others. Many of these waters, and especially the thermal ones—Buxton, *et cetera*—produce effects in general estimation far beyond what can be accounted for, either by their chemical composition and the power of their known ingredients, or by their temperature as shown by the thermometer, in comparison with those of ordinary water baths.

ALKALINE WATERS.—Carbonate and bicarbonate of soda are the characteristic ingredients in such mineral waters. The thermal springs of Teplitz and Ems come under this class, also the Vichy waters, which have long been noted for the cure of stone and gravel; but of late years they have been the subject of discussion among French physicians as to their efficacy in these disorders.

Among the mineral waters in this country which contain carbonate of soda are those of Ilkeston in Derbyshire, near Nottingham, and Malvern in Worcestershire, an analysis of the latter being appended. These waters have only recently been minutely analyzed in the Editor's laboratory:—

	St. Ann's Well, Great Malvern Editor.	Holy Well, Malvern Wells, Barrack.
	In the Imperial gallon.	
Alumina,.....	—	traces
Carbonate of iron,.....	0.0331	0.22470
“ lime,.....	0.4310	1.02480
“ magnesia,.....	0.4111	1.48400
“ soda,.....	0.2844	0.93310
Chloride of magnesium,.....	0.1448	—
“ sodium,.....	0.8768	0.94570
Iodide of potassium,.....	0.00021	—
“ sodium,.....	—	0.00029
Silicic acid,.....	0.2057	0.13250
Sulphate of lime,.....	1.1521	1.65690
“ soda,.....	0.4382	0.09760
Organic matter,.....	—	traces
	3.9772	6.55850
Specific gravity,.....	1.0013	1.0012
Carbonic acid in cubic inches,.....	1.38	6.72
Temperature,.....	48°	46°

The above waters issue from the rock at the rate of

about three gallons a minute, and they have been renowned as highly advantageous as an external application to indurated scrofulous tumors, ulcers, and many eruptive diseases, owing to the trace of iodine, as well as efficacious and beneficial when taken internally, for acidity, dyspepsia, *et cetera*—if so, why not take the active ingredient *per se* at home?

Dr. BOOKER thus apostrophizes the Holy Well—

Ever could I stray
Beside thy stream thou purest spring that flows;
Climb each bold eminence, and daily find
Some object new for wonder—ever gaze
On the wide scene around me, and regale,
When thirst demands, or pleasing taste invites,
At thy clear rill that sparkles at my foot,
And think it luxury.

Chemically it is not the purest spring that flows, that of St. Ann being much purer. *Poetically*, however, it may be.

Silicious Waters.—Most mineral waters contain traces of silicio acid, but some hold it in such quantity that the term *silicious* is applied to them. In the boiling springs of Geyser and Reikun in Iceland it amounts to nearly the half of the solid constituents. The action of such water—of course the silica is united to an alkali—will be similar to those of the soda or potassa waters. Annexed are analyses of several of the most important mineral waters on the Continent:—

	Spring Carlsbad. Temp. 16° sp. gr. 1.0047	Emm. Kesselbrunnen. Temp. 11° sp. gr. 1.0034	Seiters. Temp. 60° sp. gr. 1.0036	Gastein. Temp. 56° sp. gr.	Teplitz, Hauquella. Temp. 19° sp. gr. 1.0065	Wildbad. Temp. 60° sp. gr.	Kissingen. Temp. 55° sp. gr.	Kreuznach, Karlsbader- brunnen. Temp. 61° sp. gr. 1.006	Pyrmont Trinkquelle Temp. 57° sp. gr.
Carbonate of baryta.....	0.27	0.26	1.54	0.22	0.37	0.20	0.80	3.64	4.90
“ iron.....	—	—	—	—	1.82	—	—	—	—
“ lithia.....	23.70	11.40	18.67	3.97	3.25	3.40	35.50	6.13	59.88
“ lime.....	0.06	0.03	—	trace	0.80	—	trace	6.51	0.48
“ manganese.....	13.69	7.88	15.95	0.35	0.53	0.70	25.00	4.73	3.23
“ soda.....	96.95	107.50	58.55	6.90	26.84	5.30	8.20	—	—
“ strontia.....	0.07	0.10	trace	trace	0.19	—	trace	—	—
Sulphate of lime.....	—	—	—	—	—	—	25.00	—	72.21
“ lithia.....	—	—	—	—	—	—	—	—	0.09
“ magnesia.....	—	—	—	—	—	—	—	—	26.97
“ potassa.....	—	5.40	—	0.55	4.34	0.20	—	—	0.42
“ soda.....	198.63	—	2.48	14.95	—	4.00	20.00	—	21.45
“ strontia.....	—	—	—	—	—	—	—	—	0.20
Phosphate of alumina.....	0.02	0.018	—	—	0.22	—	—	—	0.14
“ lime.....	0.01	—	—	trace	—	—	—	—	—
“ soda.....	—	—	2.81	—	trace	—	1.70	—	—
Chloride of ammonium.....	—	—	—	—	—	—	0.50	—	—
“ calcium.....	—	—	—	—	—	—	—	25.61	—
“ lithium.....	—	—	—	—	—	—	—	0.56	—
“ magnesium.....	—	—	—	—	—	—	68.50	6.79	11.26
“ potassium.....	—	0.45	3.58	—	1.04	—	9.10	4.07	—
“ sodium.....	79.75	76.34	162.85	3.40	4.33	18.20	620.50	596.65	—
Iodide of magnesium.....	—	—	—	—	—	—	trace	—	—
“ sodium.....	—	—	—	—	0.56	—	—	0.44	—
Bromide of magnesium.....	—	—	—	—	—	—	7.00	66.02	—
Fluoride of calcium.....	0.24	0.019	—	—	—	—	—	—	—
“ sodium.....	—	—	—	—	1.30	—	—	—	—
Alumina.....	—	—	—	0.50	—	—	1.80	4.32	—
Silicic acid.....	5.77	4.14	2.89	2.02	3.12	3.90	22.50	0.31	4.96
Glairine.....	—	—	—	trace	0.90	—	5.30	14.72	—
	419.22	213.67	269.32	25.96	49.61	35.90	857.40	760.53	206.19

SEA WATER—*Aqua Marina*.—The waters of the ocean and inland seas are comprised under this head. It is rather a remarkable fact that the Dead Sea differs greatly in its constitution from sea-water, and might, as stated by PEREIRA, to whose excellent work the Editor is indebted for most of the preceding valuable information, be ranked amongst mineral waters.

According to the analysis of MARCET, the water of the Dead Sea contains 24.6 per cent. of fixed matter, and possesses an extraordinary density, 1.211—

	Centesimaly represented.
Chloride of sodium.....	10.360
“ calcium.....	3.920
“ magnesium.....	10.246
Sulphate of lime.....	0.054
Water.....	75.420
	100.000

The amount of saline matters varies considerably in

different seas, as instanced by the following results from PFAFF. The solid constituents are in ten thousand parts of the water of each:—

Mediterranean.....	410
English channel.....	380
German ocean {	
At the Island of Föhr.....	340
“ “ of Norderney.....	342
In the Frith of Forth.....	312
At Rützelbüttel.....	312
Baltic Sea {	
At Apenrade in Sleswick.....	216
At Kiel in Holstein.....	200
At Doberan in Mecklenberg.....	168
At Travenmünde.....	167
At Zoppot in Mecklenberg.....	76
At Carlsham.....	66

To assume that the average quantity of solid matter is three and a half per cent., and the density about 1.0274 will be very near the mark.

Annexed are the analyses of SCHWEITZER and LAURENS, of two samples of sea-water:—

	English Channel. Schweitzer.	Mediterranean. Lauroux.
Chloride of sodium	27.05948 ..	27.22
Chloride of potassium	0.76552 ..	0.01
Chloride of magnesium	3.66658 ..	6.14
Bromide of magnesium	0.02919 ..	—
Sulphate of magnesia	2.29578 ..	7.02
Sulphate of lime	1.40562 ..	0.15
Carbonate of lime	0.03901 ..	} 0.20
Carbonate of magnesia	— ..	
Water	964.74372 ..	959.26
	1000.00000	1000.00

SCHWEITZER also detected iodine and ammonia, and BALARD found iodine in the Mediterranean; and no doubt it contains bromine and other constituents. In fact MALAGUTI detected *silver* in sea-water.

To render such water fit for drinking, it is evident that the greater part of these saline constituents must be removed; and, as TOMLINSON remarks, it has long been a desideratum to enable ships' crews to employ sea-water for different culinary purposes, with the view of removing the necessity of carrying large supplies of fresh water. Almost innumerable are the contrivances invented to meet this end, and, according to the above-cited authority, the most effective is GRANT'S, by which the cooking of victuals and the purifying of water are carried on synchronously. The apparatus is called *the distilling and cooking galley*. The galley contains the fires and vessels necessary for cooking. During the time when the fires are ignited, a portion of the heat is applied to the external part of vessels containing sea-water; the water boils, and steam distils over, leaving, of course, the salts in the still. The steam condenses in a worm, and is nearly pure water, which, of course, is rapid; but the taste may be improved by access to open air and agitation. Where steam-power is used, GRANT'S apparatus affords a ready and effective means of separating fresh-water from salt. PEREIRA says that CLARK'S patent improved pyrohydropneumatic apparatus for easily converting sea-water into fresh is a convenient form of still adapted for sea service. Congelation separates fresh from sea-water. In freezing the pure water only congeals, not the saline ingredients; hence the ice of the polar seas yields fresh water.

Physiological Effects and Uses.—Sea-water taken into the stomach excites thirst, nauseates, and in large doses occasions vomiting and purging. The repeated use of it in moderate doses has been found of service on account of its alterative and resolvent operation in scrofulous affections, especially glandular enlargements and mesenteric diseases. Its topical action is more stimulant than ordinary water. It is used as an embrocation in chronic diseases of the joints. Baths of it are not so exhausting as those of common water. It is a popular opinion, perhaps well founded, that patients are less likely to catch cold after the use of salt than of fresh water.—*Pereira*.

ARTIFICIAL AND AERATED WATERS.—About forty years ago, when the fabrication of mineral and spa waters commenced, a very violent opposition arose with regard to them, especially from the members of the faculty. They were said to be devoid of all the good qualities of the natural ones—to be minus a certain *conditio sine qua non*, in the shape of a *spiritus rectus*, or vital force,

which imparted the medicinal qualities. The Editor has lived to see such statements reversed. Chemistry, the great revealer of hidden treasures, has demonstrated to a certainty what the constituents of the natural waters are; and thus one is now enabled to produce artificial waters quite equal, if not superior to the natural ones. At the Brighton pump-room many artificial waters are prepared imitative of those of Carlsbad, Pyrmont, Vichy, Kreuznach, Ems, Seltzer, and many others, too numerous to detail. Messrs. ELLIS of Ruthin prepare a beautiful imitation of the Seltzer water which, on being analysed by the Editor, yielded exactly the same constituents as the far-famed Bohemian spring. The artificial is certainly more palatable than the natural water, owing probably to the freshness of the carbonic acid infused into it by the admirable apparatus of TYLER, which will be explained further on. To dwell particularly on artificial waters would be tedious and uninteresting to the reader; it is sufficient to state that in their manufacture the salts, in the same proportion as contained in the natural spring, are dissolved in as pure a water as possible, and are then more or less charged with carbonic acid or other gases.

It was PRIESTLEY who, in 1772, proposed to impregnate water direct with carbonic acid, and in 1774 prescriptions for the artificial production of Selters and Pyrmont waters, founded on an accurate analysis of the same, were published by BERGMANN.

Some years ago LIENIG analysed the Friedrichshaller water, and it is now prepared in large quantities exactly with the salts, *et cetera*, and in the same proportion as given in his results; and if one may judge by the success the imitation has met with, the artificial has almost entirely supplanted the natural beverage. The Editor may here remark, that it is to a certain extent immaterial whether one dissolves carbonate of magnesia, carbonate of lime, sulphate of lime, chloride of sodium, sulphate of soda, *et cetera*, or, on the other hand, chloride of magnesium, chloride of calcium, carbonate of soda, and sulphate of soda, if care be taken that the proportion of the respective bases and acids are strictly in accordance with the figures given by analysis; since they will, in all probability, combine in the same manner as they are associated in the natural spring. The rapid increase and spread of the manufacture of artificial waters, is the best proof that physicians find the medical and therapeutic effects of them are *identical* with those of the natural ones, whilst their *identity* in a physical and chemical point of view can hardly be questioned.

Now that the chemist is able to distinguish the ingredients actually efficacious in a water, a much more active mixture than the native spring can be prepared. To show the extent to which the manufacture of aerated waters has advanced, Messrs. ELLIS and SON, the celebrated manufacturers of soda and other carbonated beverages, inform the Editor, that at Ruthin alone, North Wales, they send out yearly *many thousand gross of effervescing beverages*. So that with other factories at London, Malvern, Liverpool, Manchester, Glasgow, *et cetera*, the trade has within the last few years become an enormous one.

Soda-Water.—This is certainly the principal aerated

water manufactured. How many thousands or millions of bottles of it are drunk annually either alone or mixed with sirups, wines, or spirits? The materials for soda water are carbonate of soda and tartaric acid.

It is a well-known fact that a large portion of the soda water in general use is simply carbonated water, without the alkali, and as such, is a safe and agreeable beverage; but the physician, or the invalid, or any one who seeks therapeutic and corrective influences of the water, will be greatly disappointed in the use of these fluids, as they are inert, and for such purposes worse than useless. It is difficult to find a person who is not subject to occasional annoyance from acidity. To such an individual a glass of soda-water has been found to impart immediate relief. The carbonic acid appears to produce a peculiar sedative action upon the irritated mucous lining of the stomach, and the alkali neutralizes the excess of acid, and restores the organ to a condition of comfort which few but those who have suffered from the annoyance of heartburn can appreciate. Dr. BENGE JONES, in a treatise upon gout, strongly recommends the use of soda or potassa waters, but laments that the waters so-called in commerce are not alkaline at all; and numerous physicians of eminence have expressed the same complaint.

Some time ago the Editor was greatly pleased in inspecting the admirably conducted establishment of ELLIS at Ruthin, North Wales. Everything was so nice and clean; and, as for the water employed from a deep and splendid well upon the premises, it might be said to be absolutely pure; and it is on this account that he considers the soda, potassa, and other beverages prepared in these works superior to any other in the market. Messrs. SCHWRIPE and others, no doubt, manufacture equally well; but they do not start with *as pure a fluid*. The quantity of soda or potassa in each bottle at Ruthin is twenty-five grains of the bicarbonate of either alkali; and the carbonic acid is equal to about two hundred and fifty or sixty cubic inches, showing how well the gas is compressed. The water from the well only holds *two grains* of solid matter in solution, and *has not a trace of organic matter*; hence it is not liable to alterate or decompose, if kept for any length of time. The apparatus will now be described; and for the following, the Editor is again, as in several instances, indebted to TOMLINSON's excellent Cyclo-pædia.

An elegant little apparatus has been brought into use within the last few years, patented by M. MATHIEU, as an improvement upon an earlier invention. It is calculated for the preparation of aerated beverages in private houses rather than for sale, since it can yield but a small quantity at a time. There are two oval glass vessels—the larger one placed vertically over the smaller. There is a passage of communication from the one to the other, and in this passage there is a tap for drawing off the aerated liquid. The upper or larger glass is filled with water by removing the cover; and the lower or smaller glass is supplied with the powders. These powders are, as in other cases, of different kinds, according to the sort of beverage to be produced. A small pipe descends from nearly the top of the upper to nearly the bottom

of the lower vessel; a little water descends through this pipe, mixes with the powder, and produces gases; and these gases ascend to the water in the upper vessel. Of course, such gases only as are soluble in water are generated. The gas chiefly used is carbonic acid, of which water will absorb its own bulk, and by pressure can be made to take up another volume. As the gas accumulates in the upper vessel, the pressure increases, and the water is thus enabled to take up its additional supply. The two vessels are generally surrounded with a netting of wire or cane for security. In the simpler forms of the apparatus, nothing further presents itself; but in M. MATHIEU's improvement there is a refrigerating contrivance. The upper vessel is surrounded by an external shell and sheath, so as to leave an intervening space; and into this may be introduced either ice, or cold water, or freezing mixture.

GAILLARD and DUBOIS' gazogenic, or aerated water apparatus, is a much more complicated contrivance. It contains three distinct chambers or vessels—one for the water to be aerated, one for the effervescing powders, and one to contain a small quantity of water which is to act upon the powders. It is necessary to separate all three vessels when the apparatus is to be prepared for use; and this is one cause of its complexity. When all three have been properly supplied, the finger is pressed upon a stud or button at its top. This pressure opens a valve which allows the water in the small upper vessel to descend into the one containing the powders. The gas, thus generated, can only escape from the powder-vessel by descending a small tube which dips into the larger one; and the water with which this larger vessel is nearly filled becomes impregnated with the gas. A second finger-stud governs the valve of a small pipe, which enables the aerated water to flow from the apparatus, which is elegant in construction, but has not the elegance of simplicity.

Mr. MASTER's aerating machine is similar in principle to MATHIEU's, though differing in details. The powders are placed in the lower part, and the water in the upper; a little water descends to the powders, and the generating gas ascends. A stud, acted upon by the thumb, draws off the beverage when required.

Messrs. TYLER, HAYWARD and Company's patent double soda-water machine is adapted for bottles, and can make three hundred dozen *per diem*. There are two distinct machines in one frame, which can be worked together or separately. It consists of a condenser divided into two by a partition inside. Each half has an agitator, worked by a wheel. There are two condensing pumps, with regulating taps for admitting aerated water. The pumps are worked by a beam. The beam, by its reciprocating motion, causes the plungers beneath the pumps to ascend and descend in their barrels, forcing at each successive stroke the gas and water together into the condenser. About ten minutes are required to get the charge up, and the bottling then goes on uninterruptedly.

Messrs. TYLER and Son have invented single and double soda-water machines of ingenious construction. Mr. W. Cox of Manchester has patented an apparatus

in which the impregnating gas may be sustained at a pressure sufficient to cause its absorption by the water without the aid of force-pumps. BAKEWELL'S apparatus is another contrivance, applicable to the preparation not only of cooling drinks, but of effervescing draughts also, whether tonic, aperient, diuretic, anti-acid, or pectic. In short, every aerating apparatus may be said to comprise these two parts—one to produce a gas, and one to mix it with plain water, or water containing carbonates of soda, potassa, magnesia, *et cetera*, or orangeade, lemonade, gingerade, and the like.

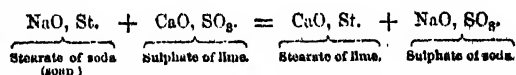
ANALYSIS OF WATERS.—*Method of Testing for and Determining Nitrous and Nitric Acids.*—Almost all river waters, and especially the shallow well waters of towns, contain variable quantities of nitrous and nitric acids generally in combination with lime, as nitrite and nitrate of that base. Their constituents have hitherto been generally overlooked by analysts, but on their presence and quantity the chemist may form a more correct idea as to the contamination of the water by organic matter than by any other means. The Editor, therefore, attaches the greatest importance to the determination of these constituents, especially when the water is selected for domestic use.

It has been previously stated that ammonia is one of the principal products of the decomposition of animal matter. This ammonia very speedily becomes oxidized and converted into nitrous acid— NO_2 —which, by longer exposure, is further oxidised into nitric acid— NO_3 . The above-mentioned acids depend for their origin on the presence of organic matter capable of yielding ammonia, and the solvent action of waters upon lea-l, is almost entirely due to these acids.

Method of Determining the Hardness of Water.—The so-called *hardness* of a water is dependent, as already stated, upon the presence of a certain proportion of the salts of lime and magnesia, which possess the property of decomposing an equivalent quantity of soap, and rendering it useless as a detergent. These salts are bicarbonates of lime and magnesia, and the sulphates of the same basis. The former impart to water its *temporary*, and the latter its *permanent* hardness. The two bicarbonates are decomposed by boiling; the insoluble monocarbonates being deposited, and, mixed with small quantities of the other mineral constituents, form the incrustations which are frequently observed on kettles and boilers in which hard water is employed. In order to determine the temporary and permanent hardness of water, the following method is adopted:—

Into a six ounce stoppered bottle put one thousand grains of water; agitate briskly, and suck out the air by means of a piece of glass tube. This is necessary in order to remove the free carbonic acid, which might interfere with the soap test. Fill the graduated burette with soap test solution, add one measure, and agitate briskly. If no lather is produced, add more, and shake again. Continue adding the soap-test till a permanent lather is produced. Even in moderately hard water a white opalescence appears immediately on adding a few drops of the test, and a white curdy mass will be seen to collect on the surface. Pure soap, such as is used in

making the test solution, is a stearate or palmitate of soda, which is readily soluble in pure water; but when it is added to a water containing salts of lime and magnesia, the soluble soda-soap is decomposed, and an insoluble soap of lime and magnesia produced. The decomposition is represented in the following equation:—



A similar decomposition takes place with soluble salts of magnesia, and hence, when hard waters are used for washing, not a particle of soap will act as a detergent until the whole of the lime and magnesia is removed.

In accurate analysis it is important to make a double determination of the hardness—one before the water is boiled, and another after a portion has been boiled for about six hours. The degree of hardness after boiling represents the hardness due to sulphates and chlorides of the alkaline earth metals, while the difference between the hardness obtained after and before ebullition indicates that which is due to the carbonates of those metals. For example, if a water has a hardness of fourteen degrees before boiling, and of four degrees after, the water is then said to have a temporary hardness of ten degrees, and a permanent hardness of four degrees.

That the determination of the hardness of water is important cannot be denied, since it furnishes a certain guide to the proper association of the acids and bases when one comes to arrange the results of a complete analysis. But until chemists are agreed upon the character of a type water, its true value cannot be properly appreciated.

Determination of the free Carbonic Acid in Water

—Water which has been allowed to stand for some hours in an open vessel becomes insipid and mawkish to the taste, or in popular language, it is flat. This is owing to the escape of carbonic acid, which occurs in many spring and well waters. Hence, in giving a correct opinion of the value of a water for dietetic purposes, it is sometimes necessary to determine the number of cubic inches of free carbonic acid in a given measure of the water. This is an operation which ought to be performed at the source, and is best done in the following manner:—A well-stoppered glass bottle holding a gallon is required for the purpose. Put into it two fluid ounces of strong ammonia, and two fluid ounces of a saturated solution of chloride of calcium. If both materials are pure, the mixture will remain perfectly bright. After observing that no milkiness is produced, depress the bottle into the stream or well, and fill it gradually, taking great care not to dip the neck entirely beneath the surface, but only partially, so as to allow space for the air to pass out, while the water is flowing in. This precaution is essentially necessary, since, if the water were to be agitated by the air escaping from the bottle, much of the free carbonic acid would be expelled by the agitation so occasioned, and hence erroneous results would be obtained.

After carefully filling the bottle with the water, it is

to be stoppered and left for three or four days. After that time, the whole of the carbonic acid will have been precipitated in the form of carbonate of lime. This is to be filtered off, dried, and weighed. From the total weight of the precipitate is calculated the quantity of carbonic acid according to the following formula—

$$50 : 22 :: \text{the weight of carbonate of lime} : x$$

The value of x will give the quantity of carbonic acid contained in the water.

Some, however, of this carbonic acid is in combination with lime and magnesia, and it is therefore necessary to determine the quantity, in order to ascertain how much exists in a free state. This requires a separate operation. A gallon of the water is introduced into a large glass flask, and boiled for six hours. The diminution in bulk occasioned by evaporation is made up with pure distilled water. The precipitate produced by boiling is collected on a filter, and the portion adhering to the bottom of the flask is dissolved by a little dilute hydrochloric acid. The precipitate on the filter is dissolved, and the two solutions mixed together. The solution will contain traces of silica, iron, alumina, and phosphate, which may be disregarded; its chief components are carbonate of lime and carbonate of magnesia, which being separately determined, their weight is to be deducted from the weight of the precipitate obtained from the bottle in which the ammonia and chloride of calcium had been used. From the difference may be calculated the quantity of carbonic acid per gallon. One grain by weight measures as nearly as possible two cubic inches. Therefore, if the difference in the weights of the two precipitates amount to a weight of carbonate of lime containing twenty grains of carbonic acid, the water will be proved to contain forty cubic inches of that gas in a free state per gallon.

Determination of the Alkalinity of Water.—By the alkalinity of water is understood the quantity of potassa or soda which may be present in combination with carbonic acid. For ordinary drinking purposes it is quite unnecessary to perform this operation, but when water is used for brewing, dyeing, and starch-making, the presence of the alkaline carbonates is a matter of great consequence. The following method, though by no means perfect, is generally adopted. Two gallons of the water are evaporated in a large platinum dish down to about four fluid ounces. This is filtered from the deposit, colored with tincture of litmus, and then neutralized by a standard solution of sulphuric acid, containing in a hundred cubic centimeters as much acid as will neutralize one grain of alkaline carbonate.

Determination of Chlorine.—Half a gallon of water is evaporated to about four fluid ounces. Dilute nitric acid is then added to dissolve the precipitated carbonates. The whole is transferred to a beaker glass and filtered, the filter being thoroughly washed. To the solution is now poured in a slight excess of nitrate of silver, which throws down all the chlorine as chloride of the metal. The menstruum is now boiled, filtered, and the precipitate well washed with hot distilled water, then dried at 212° , ignited in a porcelain crucible, and weighed—143.5 of chloride of silver contain 35.5 of chlorine.

In determining the chloride of silver, the filter containing it should be completely exsiccated, then ignited very gently in the porcelain crucible; as soon as it ceases to burn, the carbonaceous residue of the filter should be slightly moistened with concentrated nitric acid, and again burned. By repeating this process several times, until all the carbon of the filter is destroyed, any loss of chloride of silver will be avoided; but before weighing, it is well to moisten the residue with hydrochloric acid, and ignite, in order to convert any reduced metal into chloride.

Determination of Sulphuric Acid.—Half a gallon of the water is, as in the preceding instance, evaporated to three or four ounces, and acidified chloride of barium is then to be added, and the whole boiled, and left for twelve or more hours in repose, then filtered, and the sulphate of baryta washed thoroughly and dried. 116.5 of sulphate of baryta represents 40 of sulphuric acid.

Directions for determining in Water the Non-volatile Organic Matter—Silica, Iron, Alumina and Phosphates; Lime and Magnesia.—Evaporate slowly half a gallon of water to about a pint, over a gas flame; then transfer the dish to a sand-bath, and continue the evaporation till the bulk is reduced to about two fluid ounces. Now accurately weigh a clean platinum dish. Scrape the deposit carefully from the bottom of the porcelain basin, and rub off that which cannot be removed by the platinum knife with the middle finger; rinse the whole into the platinum dish, and then evaporate to dryness on a water-bath. Be careful to observe that every particle of the deposit is removed from the porcelain vessel. When the residue is dry place the dish in an air-bath, and heat it for half an hour or an hour at a temperature of 260° .

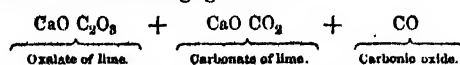
The object of heating the residue to this temperature is to expel the water of crystallization combined with sulphate of lime, which is almost an invariable constituent of well and river waters. Note down the weight. The difference between the weight of the basin when empty and that of the dish and residue will, of course, represent the actual weight of the residue in half a gallon of the water. The residuum being thoroughly desiccated and weighed, place it on a platinum triangle, over a good gas flame, or the flame of a BERTZELIUS lamp, and ignite until the blackening produced by the carbonization of the non-volatile organic matter disappears, and the mineral constituents are white. The time required to produce this change should be carefully noted. If nitrates or nitrites be present, as is invariably the case in waters containing sewage and other animal matters, then gently facilitate combustion of the organic matter, and the residue becomes white in a few moments.

On the other hand, if the water be contaminated with organic matter which has undergone but little decomposition, and especially if urine be present, the carbonaceous residue will require very lengthened ignition in order to consume the carbon. If it be necessary to heat to redness for any length of time, some of the carbonic acid in combination with lime and magnesia will be expelled, and consequently the loss of weight occasioned by the ignition would not correctly represent the actual quantity of organic

matter. It is, therefore, necessary to *recarbonate* the lime and magnesia. This is done by moistening the residue with a few drops of a strong solution of carbonate of ammonia, and again drying it at 260° till it ceases to lose weight. The dish being now weighed again, and the weight noted, the difference will represent the quantity of non-volatile organic matter present with the mineral constituents. By the continued ignition which is necessary to burn the organic matter, the *silica* is rendered *perfectly insoluble*. To the residue in the platinum dish is now added a fluid ounce of water, and, drop by drop, strong hydrochloric acid—about one in two fluid drachms—until effervescence ceases. Particular attention should be paid to the odor of the gas evolved; if it smells of sulphide of hydrogen, this will be a further indication of the contamination of the water by *animal refuse*.

After the effervescence has ceased, the dish should be gently heated on a water-bath and the solution filtered. The silica left on the filter should be washed well with hot distilled water, till a drop of the washings, evaporated on a platinum knife, no longer leaves a trace of residue. The filter containing the silica is dried, ignited in a weighed platinum crucible until the whole of the carbon is consumed, and then weighed. The filtrate from the silicic acid, after the washings have been added, is to be neutralized and made slightly alkaline with ammonia. The iron, alumina, and phosphates of the alkaline earths are precipitated, then filtered and washed with the same precautions as given in the determination of the silica, and when dried, weighed. As the iron, alumina, and earthy phosphates occur in water in very small quantity, rarely exceeding together a grain per gallon, it is for general purposes quite unnecessary to separate them. The precipitate produced by ammonia is usually recorded as *iron, alumina, phosphates*. After the precipitate is completely affused, and the washings are added to the filtrate, the lime is next to be thrown down, and this is done by adding oxalate of ammonia in excess; allow the whole to stand till the supernatant fluid becomes bright. Add the washings to the filtrate.

The precipitate is to be dried, ignited, and weighed. By ignition the oxalate of lime is converted into carbonate, and is weighed as such. The following decomposition occurs during ignition:—



As a portion of the carbonic acid of the carbonate of lime might be driven off during the heating, it is advisable to moisten the residue in the crucible with strong carbonate of ammonia, once or twice igniting after each addition, and taking the weight when it becomes constant. Fifty of carbonate of lime represent twenty-eight of lime. The washings being evaporated and added to the filtrate, about half a fluid ounce of a solution of phosphate of soda is added, and the menstruum allowed to repose for twenty-four hours in a moderately warm place. The magnesia is thus precipitated as phosphate of magnesia and ammonia— $2\text{MgO}, \text{NH}_4\text{O}, \text{PO}_4$. This salt must be well washed with dilute ammonia—one part alkali to six of water—dried, ignited,

and weighed. By burning, the precipitate is converted into pyrophosphate of magnesia— 2MgO PO_4 —from which the quantity of magnesia is ascertained. One hundred and twelve of the pyrophosphate contain forty of magnesia.

Determination of the Alkalies.—The determination of the alkaline salts in water is generally omitted in ordinary analysis; but it must be acknowledged that when water is required for certain purposes, as for instance, for brewing, it is very important to determine not only the quantity of potassium and sodium present, but especially the form in which they occur, whether as chlorides or as carbonates. For brewing purposes it is usually considered that waters containing sulphate of lime are best suited for the manufacture of pale ales, since beers made with selenitic waters are paler than those made from water free from gypsum; but notwithstanding the presence of sulphate of lime, if potassium and sodium be there as carbonates, it is impossible to obtain a pale infusion of malt, owing to the alkaline carbonates extracting certain constituents which are not soluble in water free from alkalies. The following is the best method of determining the alkalies. Half a gallon or a gallon of water is evaporated to dryness in a porcelain dish in the usual manner. The residue is dissolved in hydrochloric acid, and evaporated on a water-bath to dryness. The soluble constituents are then extracted by water, and to the aqueous solution is added an excess of baryta water. After the precipitate has subsided, the solution is filtered, and to it is added a *very slight* excess of pure carbonate of ammonia. The excess of baryta thus precipitated is filtered off, and the solution which now contains only the alkalies, as chlorides, is evaporated to dryness in a weighed platinum dish, to determine the quantity of mixed chlorides of potassium and sodium. The weight being noted, the chlorides have now to be separated. This is accomplished by dissolving in water, adding excess of bichloride of platinum, and evaporating to dryness on a water-bath. The mixed platinum salts are now treated with alcohol and ether, filtered and washed with a mixture of ether and alcohol till the washings come through perfectly colorless. The precipitate of bichloride of platinum is then weighed, and the quantity of chloride of potassium it represents is calculated. This is deducted from the weight of mixed chlorides, the actual quantities of potassium and sodium calculated.

Having now determined the actual proportions of all the ordinary acids and bases present in the water, one has then to associate the acids and bases together as salts, in the form in which they probably existed in the water previous to analysis.

The association of the acids and bases is founded entirely on arbitrary rules, the usual plan being to unite them in the order of their respective affinities—the strongest acids with the strongest bases. But this is obviously an incorrect method, since it is often found that two chemists analyzing the same water will give entirely different forms of analysis, although they may both have found the same proportions of the respective acids and bases; the one will associate all the sulphuric acid with potassa and soda, the other may place it with

lime, and regard the alkaline bases not as sulphates but as carbonates. Now, as before shown, it is a question of the greatest importance, when water is required for special purposes, to determine not only the proportions of acids and bases present, but the form in which they are associated. In order to do this properly the analyst must have regard—1st, To the geological characters of the source of the water; 2d, to the nature of the country through which it flows; 3d, to the contaminations from sewers and manufactories to which the water is exposed.

Rain-water, it is to be presumed, cannot differ materially in the nature and quantity of its impurities, but yet it has been shown that one rarely finds two river waters of precisely the same composition. In the water of the Dec, the analyst finds only about four grains of mineral matter, because the rocky soil over which it flows is soluble only to a slight extent in native water. The water of the Trent flows over a soil abounding in gypsum, and consequently the water is very hard, while in the water of the Thames, which flows through a line of country composed essentially of chalk, the prevailing constituent is bicarbonate of lime. The presence of a superabundance of earthy salts in water, exercises an influence of some importance in many of the industrial works of the kingdom, and especially in brewing. Paradoxical as it may seem, it is now an ascertained fact, that the hardest waters, that is, such as contain most earthy salts in solution, have the greatest extractive power for the brewer; and further, that the chemical changes that take place between certain constituents of the malt and those salts, serve in the case of ale brewing to fine the beverage in the natural way, without the aid of disgusting and corrupt *stuffs* employed for this purpose very frequently.

A glance at the composition of the waters which are used by ALLSOPP and BASS, the Great Burton brewers, and by TETLEY, of Leeds, *et cetera*, gives at once the clue to the superior excellence of the manufactures of these parties over ales made from such liquids as the *Liverpool Pike*, which is not only devoid of earthy salts in the requisite quantity, but contains an amount of animal and vegetal matter in such a state of fermentation, that the action is engrafted on the glucose, and proceeds in the tun collaterally with the alcoholic fermentation, which it ultimately modifies into the lactic and acid fermentation long after the natural ferment—the gluten of the malt—has been thrown off:—

	Burton water, Dr Bottinger, Allsopp's brewery.	Leeds water, Tetley's brewery, Editor.
	Grains.	Grains.
Carbonate of lime,	15.51	19.78
“ magnesia,	1.70	0.93
“ protoxide of iron,	0.70	4.97
Sulphate of lime,	18.98	7.65
“ potassa,	7.65	18.09
“ soda,	9.05	9.73
“ magnesia,	10.12	7.11
Chloride of sodium,	—	4.74
“ magnesia,	0.79	1.72
Silica and loss,	65.28	62.07

The quantity of calcareous salts in the above waters is a proof of the beneficial action of lime in the preparation of the best malt.

ELECTRICAL PROPERTIES.—This article on water
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would be incomplete without making some allusion to its electrical properties, which are not only turned to useful account in the numerous and increasing applications of electricity, but also perform an important part in the great phenomena of nature. It would be improper, perhaps, to particularize under this head the hydro-electric machine, because although in that apparatus very large quantities of electricity are generated by the issue of steam through narrow apertures, the effect has been attributed by FARADAY to mere friction, and therefore exhibits no new property of the water itself. It is in the electricity which it generates by contact with oxidizable metals in the galvanic battery, and in the variable conducting power of the liquid according to its greater or less admixture with different acids and salts, that water assumes its chief importance in electro-chemical action. In the working of the battery, for example, it is the decomposition of the water which accompanies the oxidation of the zinc or other positive metal, and not the action of the acid or salt superadded, that really produces the electricity. This was demonstrated by KOHLRAUSCH, who showed that the electric tension was the same at the poles of two similar batteries, one of which was charged with distilled water and the other with a mixture of water and sulphuric acid. The remarkable effect of certain acids and salts in increasing the energy of the current, is chiefly due to the peculiar property which they possess of increasing the conducting power of the liquid. The following table exhibits this property in a very striking light:—

	Conducting power
Distilled water,	0.0125
Do. with 1-20,000 of nitric acid,	0.075
Sulphate of copper, saturated solution,	5.42
Sulphate of zinc, do.	5.77
Nitrate of copper, do.	8.99
Chloride of sodium, do.	31.52
Sulphuric acid diluted with eleven measures of } distilled water,	88.68
Nitric acid, specific gravity 1.31,	93.77

From which it appears, that the addition of only one twenty-thousandth part of nitric acid to distilled water increases its conducting power about sixfold, and that one measure of sulphuric acid, added to eleven of distilled water, increases its conducting power seven thousand times. Distilled or absolutely pure water is therefore a very bad conductor of electricity; but it has been shown that water of this extreme purity is not to be found in nature; that even rain-water is more or less impregnated with certain foreign ingredients, and that the waters of rivers and wells vary immensely in the amount and character of their saline constituents. It is therefore that, in rainy weather, the moisture of the atmosphere, acting the part of a conductor, destroys the insulation of the telegraph wires, and obstructs the working of the instrument; it is therefore that the earth, and still better, the briny waters of the ocean, not only transmit natural currents, but submit themselves as willing agents to the purposes of telegraphic communication; and lastly, it is to the moisture of the atmosphere, floating in clouds charged with an opposite electricity to that of the earth, that the grand phenomena of the thunderstorm chiefly owe their existence.

WINE.—*Vin*, French; *Wein*, German; *Win*, Anglo-Saxon; *Wyn*, Dutch; *Vino*, Spanish and Italian; *Vinho*, Portuguese; *Vinum*, Latin; *Oinos*, *Oinos*, Greek. —All these denominations were probably derived from *Oinos*, with the digamma prefixed, answering to F or V in English, as *Voinos* and thence the Latin *Vinum*. The Hebrew term for wine in general, is *Yayin*, but if medicated or, in other words, made more potent by the admixture of herbs or drugs, it was denominated *Shekhar* or *Strong Drink*, in common with other fermented liquids. The Greek name being the parent of the Latin, confirms the tradition that wine came into the more Western parts of Europe from Greece by way of Italy, and from Asia into Greece.

When man was driven from that peaceful asylum originally assigned to him by his Creator, and condemned to earn his bread by the labor of his hands, his attention was no doubt powerfully exerted in procuring the necessities of life; such as food, clothing, and habitation. As a cultivator of the earth, he must have been constantly employed, and, as his occupation varied with the seasons, his mind was continually disciplined on contrivances to diminish and sweeten his toil. His activity, when thus excited, soon extended its influence to every department of life, and having procured its necessities, he was doubtless early led to task his ingenuity in the attainments of its luxuries. Among these, the preservation of fruit and their juices, however rudely practised, might have led to the use of inebriating drink—a beverage which was discovered by some of the most savage nations, and is deemed a luxury by the almost universal testimony of mankind.

Wine, when an uncompounded word, signifies the fermented juice of the grape only; but when compounded, it is applied as a general term to the fermented product of other fruits in conjunction with the name of those fruits, tendrils, stems, leaves, or similar substances from which it is made, as gooseberry-wine, ginger wine, and all the varieties denominated *domestic wines*.

Wine of the grape is divided into dry and sweet, and under one or the other of these great divisions every variety is included. The characteristics and causes of each of these divisions will be fully explained.

The juice of the grape, which is usually called *must*, is known to ferment *per se* at 70°, which proves that wine was very early known; particularly in hot climates, where drink is so much required to allay thirst; and this is a further sign that the vinous fermentation was familiar long anterior to the deluge.

Carrying this idea still further towards the Creation, MILTON seems to have entertained the opinion that the fruit of which ADAM and EVE had eaten—

— whose mortal taste
Brought death into the world, and all our woe,

was of an intoxicating nature, when he says:—

Soon as the force of that fallacious fruit,
That with exhilarating vapor bland,
About their spirits had played, and inmost powers
Made err, was now exhaled.

Wine is the oldest fermented liquor, its invention being ascribed to NOAH in the traditions of the Jews

almost immediately after the deluge. The Greeks with their fabled DIONYSIUS from Egypt, originally from India, threw no light upon the discoverer; but if they learned the art of making wine from the Egyptians, that liquid may be thus traced up to the days of MOSES. HERODOTUS reports that there was no wine made in Egypt, a singular error, when Mareotic and Teniotic wines were notorious. The wine of Meröe called *indomitum* by LUCAN was far-famed. The writings of MOSES show that the kings of Egypt drank wine, as all who have perused them will not fail to recollect in reading the story of JOSEPH and the chief butler of PHARAOH. The ruined temples of Thebes also display the emblems of the vintage in bas-relief, and figures of men pressing grapes with their hands, the must flowing into goblets emblematic of the wine-press. Some have used this as an argument against fermented wine; but must unfermented, would not keep from decomposition for many hours, even in the Eastern land of miracles; nor would the simple juice have intoxicated NOAH, because to occasion ebriety fermentation is absolutely necessary, as in all other alcoholic liquors.

Next in antiquity to the volume of the Jewish faith are the works of HOMER and HESIOD, who lived so near together in point of time, that even concluding HOMER to have flourished in the tenth century before CHRIST or about the reign of SOLOMON, the difference so much discussed by the learned is of no moment in a scientific sense. HOMER mentions the names of several kinds of wine, and alludes to their potency.

The frequent allusion to wine, the praises bestowed upon it, the flowing goblets, the luxurious banquets as described by the great Grecian poet one thousand years before the Christian era, exhibit its value and his attachment to the comforts of the table and to jovial society.

HORACE was of this opinion when he says—

Homer, in praise of the profuse,
No doubt loved well the balmy juice.

The wines referred to required twenty parts of water to make them potable, as in the case of the Maronean ones. Poets are not to be literally trusted; and in the present case, as the object of HOMER was to intoxicate the giant POLYPHEMUS through his hero ULYSSES, full latitude must be given for poetical fiction, which can seldom be quoted in reference to the exact sciences. This Maronean wine was made from vineyards on the side of Ismarus, a hill of Thrace, by MARON a priest of the Sun. The circumstance of the Greeks mixing water with their wine, might after all mean no more than it does in France at the present time, where water is often mingled with common wines of the country by no means remarkable for their strength. Thus the wine of Scythos is said to have been used with half its bulk of water. The wines most in repute with the Greeks were, in the first place, the wines of Chio or Chios, which, with the Thasian, were ranked among the superior growths. Lesbos was also celebrated for its wines. Many of the Greek islands were distinguished for wines of delicacy and flavor, for the most part rich and sweet. The Ariusian wine of Chio was in high esteem as a luscious

product of one of the vineyards of the island. The Pannolian was celebrated for its healing qualities. This wine was red, from a vineyard in Lesbos. The wines of Rhodes, Crete, and the Clazomenian from the shores of Ionia, were much valued, and often taken with an admixture of sea-water, a singular custom, thought to impart smoothness to the wine. The quantity thus mingled was very small, and was always boiled before it was mingled with the wine. The Greeks classed their wines, as in modern times, into sweet and dry, but had an intermediate species. They seem to have preferred the thick sweet wines to all others, that species, for example, which the moderns denominate malmsey, differing little perhaps from the modern wine of Cyprus, or the malvasia of the Morea. Some of these wines possessed what is now called the bouquet. As soon as they were opened to the air, the perfume was immediately perceived, but this might have arisen from the infusion of odorous substances at the time of fermentation, a practice then common. Sappian wine was one of those celebrated for its odor on being uncorked. This odor, it is pretty clear, did not arise, as it does in the pure wines of France in modern times, from the natural perfume after fermentation, but from the addition of odorous substances. Port and the strong Anglo-medicated wines at present, possess no bouquet from its being destroyed by the admixture of alcohol with them artificially, rendering them heavy and dull. The wines of Bordeaux, Champagne, and Burgundy, on the other hand, have the perfume in a high degree from nature.

The wine of Chio, called the Phanean, was celebrated among the Romans, who imported both that and the wine of Argitis. The wine of Mende in Thrace was a white wine of no great strength. The wines of Zante speedily intoxicated; and those of the other Greek islands, as well as of Lydia, Phœnicia, and Cilicia on the mainland, were of good quality, producing growths the mere names of which it would be superfluous to record.

Rome, as she learned the other arts from Greece, acquired also that of making wine, as soon as she extended her power beyond the limits of her home empire. In the days of HOMER milk was substituted in the sacrifices in place of wine, because of its scarcity at Rome. The wine first made seems to have been from the grape grown in the Campania Felix. The most celebrated sites for the vine were near Naples, on the sides and at the foot of Vesuvius, now covered with the lava and ashes of that celebrated volcano; a spot in which Bacchus was said to have delighted in consequence of its rare fertility and excellent adaptation for the vine culture. The sea washes the limits of this beautiful vine-climate in one direction, and in the other delightful hills, named the Falernian, Surrentine, Massic, Gaurean, and others, arose with the choicest aspect and the most propitious slopes from the low country, giving names to the products since wedded to immortal verse. Thus the Falernian, Surrentine, Cœcuban, Setine, and other wines of the vicinity, were named from their native hills. One or two of the more celebrated writers left passages in their works which enable us to give a guess at the nature of some of the wines in use among the

Romans, whether the growths of Greece or Italy. It is certain from these that, except in the sweet wines of the South of Europe at present, no great similarity could have existed between the ancient wines and those most prized by the moderns. The writings of ATHENÆUS and PLINY give a tolerable account of the treatment of the vine under cultivation, but we learn little from them in relation to the constituent parts, flavor, or qualities of the produce. The same remark will hold good in relation to the extant works of VARRO, CATO, COLUMELLA, and PALLADIUS. In short, no source remains from which any tolerable approximation can take place as to a knowledge of quality and flavor. It is well known on the other hand that the Campanian vine once enriched a considerable territory of great fertility, and that a number of large towns which have now disappeared, once adorned that favored spot. The more famous wine was the Falernian, which some suppose to have been made on the present Monte Barbaro. The Cœcuban, a sweet wine, was made on the palmus lands of Amycle. The Falernian was of three kinds, the dry, sweet, and weak. A celebrated vintage called the Opimian, from the name of the consul that year, L. OPIMIUS NEPOS, took place in U.C. 632, the wines of which bore a great price a century afterwards. The Falernian required nine or ten years to ripen, and when aged was bitter. Some have imagined it was a dark red wine, others that it was white. The Surrentine wine was durable, and generally taken out of cups of the same name. The Massic came from Sinuessa; Trifoline from a hill near Naples; Tarentine from Mount Aulon, near Tarentum; Alban from a hill near Rome; Mamertine from Sicily, near Messina; Coreton from Etruria; Signian from Latium; and Massican from the Abruzzo. The vicinity of Rome also produced the Nomontan, Sabine, and Venafran wines. The north of Italy produced no wines of note. Spain sent the wines of Tarragona to Rome, and France those of Narbonne, Marseilles, and Vienne; but these were said to flavor too much of the smoke of the *fumarium*, or else of pitch.

The Romans suffered their vines to grow high and weakened the must. How the fermentation was managed nowhere appears. The wines were placed in a smoky receptacle to ripen, the object being the same in ancient as in modern times, to assure maturity. The Carthaginian MAGO, who wrote five hundred and fifty years before CHRIST, says, that to make the best wine, that of the sweet or luscious species, the bunches of grapes were gathered when shrivelled by the sun's heat, the bad fruit picked out, and they then were placed upon a frame of open-work covered with reeds, exposed to the sun by day, but sheltered from the dew at night. When they were sufficiently shrivelled they were thrown into a cask and trodden, and thus the first must was made. When drained, they were submitted to the wine-press for the first wine. They were then trodden a second time, and cold must added to the pressing. This second wine was placed in a pitched cask, to prevent it from becoming acid. After it had remained for twenty days in this state it was raked into another vessel, closed up from the air, and covered with a skin.

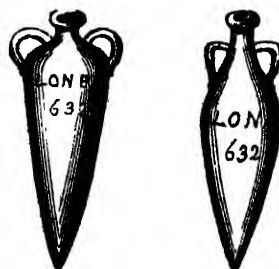
Such was the ancient mode of making sweet wines of the luscious malmsey species. For the wines in general, the fruit was gathered at intervals as it ripened, and carried to the press in baskets. The must was received in a stone or plastered cistern, and the fermentation was completed as quickly as possible. The process, there is reason to believe, was not very different from that hereafter described. In certain cases the fermentation appears to have been unnecessarily prolonged, and a part of the must that flowed from the grapes by their own pressure was reserved in a separate vessel and set aside, as it is the custom to do now in making Tokay-Ausbruch in Hungary. This must, the most valued, was often stored by itself. Sometimes it was plunged, when in a state of fermentation, into deep water, being previously hermetically sealed. Weak must was often boiled down, so that much of the aqueous portion evaporated, and it was denominated according to the quantity of the portion unevaporated. If two-thirds were left, it was called *calenum*; if only one-third, *sapa*. This was evidently copied from the Greeks, and is still practised, being called in Italy *vino cotto*, and in France *vins cuits*.

The custom of adding sea-water to wine is said to have been discovered by accident. The water was boiled down to a third part, but the quantity used differed according to the nature of the wine. The act of perfuming the wine must have ruined its delicacy; pitch, rosin, cassia, myrrh, saffron, and cypress leaves were, one or the other or several of them, thus infused. The true principles of fermentation were evidently unknown to the ancients, who had not the advantage of modern chemistry. It was the same with the causes of the difference between dry and sweet wines. There was no deficiency in the attention paid to the vines, except that they were permitted to weaken themselves by too luxuriant a growth; this in consequence tended to aid acetous fermentation. In aspect, soil, grafting, and training, all seems to have been well known in ancient times; the Greeks understanding this point better than the Romans. The Aminean grape was the species most cultivated for wine, at least in the Campania Felix, but it cannot be identified with any modern species. October was the vintage month.

The treatment of the ancient wine after the first fermentation included a further progress in the vat, and it was then placed in earthen vessels, hermetically sealed, denominated *amphora*, each of which held 6·7827 English gallons, or in other vessels of a different capacity, as the *urna*, which held just half the quantity of the amphora. If an inferior wine, or one designed to be carried to a distance, it was placed in pitched skins—the bottles of the New Testament. When designed for the amphora and cellar, after being exposed to the smoke of the *fumarium*, it had the year of the vintage or the consular year marked upon it, and was set in the ground. Under this treatment in the *fumarium* and elsewhere, some of the wines grew so thick that they could not be drunk until they were dissolved in water. That sometimes the wine tasted of the smoke is not matter of wonder. It is well known that Madeira ripens rapidly if the bottles are plunged into a hotbed or into stable dung. The amphoræ were

vessels without bases, shaped as in Fig. 615, and made of pottery clay. The consulship of the famed Opimian year is marked on some of the existing amphoræ in the way thus exhibited—L. O. NEPOS, U.C. 632. The wines of the ancients were thus different in quality from those of modern times, and could only have been relished by long habit. The different varieties which have been transmitted by name in Italy, Gaul, and the East are reckoned at a hundred kinds, rough, soft, and sweet. That the wines of the ancients were more durable from this after-management than from any knowledge they possessed of their chemical combinations when treated scientifically according to their nature, and unmingled with substances foreign to them, is evident upon a due consideration of the subject.

Fig. 615.



Regarding the wines of Asia Minor, little is known in respect to the treatment. Some kinds were kept in the *fumarium* until they became as hard as salt, and it was necessary to dissolve them too in water before they were drunk. The prices they bore, considering their age, were not extravagant; those more than a century and a half old costing less than seven shillings the English quart. In Rome the quantity of wine consumed was considerable. The servants of CATO were allowed about a pint and a half per day. The stocks of the more precious wines kept by the opulent were surprisingly large. Of the best and dearest Greek wine, that of Chio, HORTENSIVS left ten thousand casks at his decease. The celebrated MÆCENAS introduced a rare wine of his own, called *mæcenatianum*. Of the common wine made in Italy, too, the produce was large, being in one recorded case no less than two thousand one hundred and fifty gallons per acre, or eight *culei* on the jugerum or twenty-eight thousand eight hundred square feet. In these computations, however, there is much uncertainty.

Wine was drunk in Rome out of murrhine cups when the eternal city was in its greatest height of luxury and pride. What this substance was is unknown, but it appears to have come from Egypt or the East, and to have possessed an inherent perfume; many dissertations have been written upon its nature, all alike unsatisfactory.

Among names of ancient wines, is that of Helbon or wine of Tyre, called by the Greeks *kalibonion*, and alluded to by the prophet EZEKIEL—the name meaning sweet or fat; it was made near Damascus, originally by the Persians. This wine was common in England in the reign of RICHARD III., being imported in Venetian vessels. The wine of Lebanon in HOSEA, is praised for its perfume. But the different conjectures regarding the nature of ancient wines, built upon no satisfactory data, cannot, any more than their names, be of any real moment, however amusing to the scholar. It may be observed, however, that a marked distinction anciently existed between pure wine, and that which

was perfumed or medicated, as with certain wines imported into England, brandy is added for the same purpose, particularly to port wine. The Jews have preserved this distinction in scripture, by using the term *mixed* or *strong wine*; thus—In the hand of the Lord is a cup, and the wine is red; it is *full of mixture*; and he poureth out of the same; but the dregs thereof, all the wicked of the earth shall wring them out and drink them.

Leaving a subject so much of which must be conjectural, the wine of the present time, naturally the most important, comes to be considered, together with the processes adopted by the moderns in its manufacture. The variety of the plant which produces it, and the nature of the soils in which the best grape is matured, are subjects copiously treated of both by French and Spanish writers. In the catalogue of the national collection of vines at the Luxembourg in Paris, there are five hundred and seventy varieties, classed black oval, black round, white oval, white round, grey and violet oval, and grey and violet round. CHAPTAL collected fourteen hundred sorts, and CLEMENTE states that two hundred and fifty species exist in Andalusia alone. The treatment of the vine and the entire culture of the plant belong to the rural economy of the wine-producing countries. To enter largely upon this subject would be out of place here; still the following on the kind of soil best adapted for the grape, and on the best description of grapes to employ, will interest and instruct the reader.

The wine-producing countries in the Northern hemisphere are included between the parallels of 33° and 51° North; but this rule is limited by local circumstances, probably by the line of the biting North-east winds, which keep back the vine in spring. An oblique line drawn a little north of Coblentz, concave to the North, and continued to the mouth of the Vilaine, in 47° 25' North, will nearly define the vine limit. Wine once made in good quality at Estampes and Beauvais, so as to be celebrated, cannot be made there now. Thus it was once made too in the counties of England South of Cambridgeshire. Wine in 1553 was made of the muscat grape at Mâcon in Burgundy, where it cannot now be made at all. In Asia no good wine is made South of latitude 33° North, in Persia and Shiraz. In regard to the Southern hemisphere, except a little sweet wine from the Constantia vineyards at the Cape of Good Hope, none of any mark is yet produced, though much of an inferior quality is made. With the wine-producing countries of the North the world is too familiar to need the exact enumeration.

Keeping in view wines of the first and second class in excellence, nearly all which lay claim to the greatest delicacy and purity are produced in France, where science and long experience have been brought to bear upon their management. In a first-class wine there must be no mixture of any foreign matter whatever. The fermentation must be natural, and no extraneous substance introduced, not even brandy. Nothing must be allowed to prevent the development of the perfect character of the particular species expected—lightness, freshness, a rich odor conferred by nature, such as are found in Romanée-Conti, Chambertin, Vin du

Roi, or Hermitage of the first class, because of such wines only can the term *pure wine* be understood, or a standard be found by which the first-class can be established, and the test be fixed for the inferior kinds. France, Spain, Germany, Italy, Portugal, Hungary, Greece, and Sicily are the principal wine countries of Europe. Tolerable wine has also been made in the extreme South of the Russian dominions.

Passing over the vine culture, the best sites, the diseases of the vine, the training, and the incessant and laborious calling of the vine-dresser, all belonging, as before observed, to rural economy; and therefore only observing that the practice of grafting is pretty general—it may be added that some vines will bear well for a century and a half. There have been examples of three centuries, while others will not be productive for more than forty years.

The extent of the vineyards that produce the finer wines is well known to be very limited. The differences of soil and treatment do not appear sufficient to account for this fact. Although the best vines are grown on a calcareous soil, as on the chalk hills of Champagne and the albarizas of Xeres, of which carbonate of lime forms two-thirds, and in three-fourths of the more celebrated vineyards this is the case, though the necessity of such a description of soil has been denied.

In the vineyards of Andalusia, while some of the above soils contain even seventy per cent. of carbonate of lime, the remainder is a compound chiefly alumina, with a very small portion of silica, and sometimes a little magnesia. In certain spots the soil is almost pure carbonate of lime. This kind of earth absorbs every particle of moisture which falls upon it, and never cracks nor opens in the hottest summers. The albarizas are a series of calcareous hills. The best Spanish wines produced on such a soil, exhibit its virtues very strikingly in the fineness and durability of the product, and militate against the opinion expressed in some districts, that if the soil be porous, light, and free, the presence of lime is of little moment. The fences of the vineyards on the albarizas consist of the prickly pear. Adjoining the albarizas, or chalky soils, come the arenas, or sands; but these are intermingled, more or less, with calcareous particles. About Malaga, where the surface of the country is extremely rugged, the soil consists of limestone, intermixed with slaty schist, over which the rich raisins for export are produced. In the South of France, in Rousillon, the soil resembles that of Malaga, particularly near Perpignan, being slaty schist, or gravel, interspersed with calcareous matter. In some places where the soil is not six inches thick, a hole is bored in the loose rock with an iron bar, in depth about a foot, into which the plant is thrust, among the stony and arid ground. In Burgundy the soil varies much. At Chambertin it is a brown loam, full of gravel, and friable. This gravel consists of small pieces of broken limestone, in some places; in others, of marl with small shells—while, in another place, the vines grow in pure clay, but still with traces of lime in some form. The champagne district, in like manner, is almost wholly calcareous, at least where the best wines are made. Thus the famous sillery is produced from vineyards on chalk,

with an Eastern exposure. At Ay, on the Marne, on both sides of the river, the hills are chalk, and the soil often supported by terraces. *By the river of Marne, and on the hills of Rheims are the celebrated localities—proverbially so.* The chalk, whether it lie deep or superficial, produces the same effect in respect to dry wine of superior quality, agreeably to its treatment and the aspect of the vineyard. The hermitage wine has been cited in proof of the goodness of wine grown on the debris of granite.

Wines of the finest quality are undoubtedly grown upon soils where lime is not immediately visible. Sands in the vicinity of Bordeaux, and granitic soils near the Rhone, stony and argillaceous earths, are found to produce excellent wine. But hermitage, for example, although produced from vines grown among fragments of granite, is no doubt affected favorably from the calcareous soil hard by, having portions intermingled with them; nor can it be any exception to the fact as respects the finer dry wines, that their superiority is due to their connection with calcareous matter. Sweet wines are produced in almost every kind of soil. Dry wines produced on schist, for example, are poor, compared to those the fruit of which is grown on chalk land; while the sweet wines, such as those of Malaga, are good on that description of soil. The liveness, a sweet wine of France, is produced on granitic land upon which lies a stratum of pebbles, while the dry wines of the same land which produces those celebrated growths, are sufficiently mediocre. At Ay, where the finest champagne is made, the soil lies upon chalk in some places from ten to fifteen feet thick; but the superincumbent earth is full of pieces of chalk, the surface only being argillaceous; and where most so, causing some difference in the quality of the wine. Very little manure is applied to the vines that produce the best and finest wines. In argillaceous soils the roots of the vines are found not to branch off in a desirable manner; and the facility with which the soil retains the water, causes a degree of humidity prejudicial to the bud. Volcanic soils, on the other hand, give excellent wines, particularly when they are of very ancient date, and rival those the fruit of which is grown on calcareous strata; generally, too, possessing a flavor peculiar to themselves. In all cases the soil must be light, friable, porous, so that water shall not lodge around the plant. The exposition may vary. Bacchus *loves the hills* is an old, but not an unexceptionable adage, as gravelly plains may produce good wines. Sometimes, according to the nature of the country, an Eastern aspect is best; at others a Southern, and even a Northern has yielded excellent wine; much in such a case depending upon the latitude and the more obnoxious winds, as well as the atmospherical temperature. It is remarked, however, that good wine is rarely produced in narrow valleys, especially if a river flow through them.

It will thus be perceived that the nature of the soil for the dry and finest wines must be calcareous, even to pure chalk; in all events it must be sufficiently so to influence the vine most essentially during its growth; and that for sweet and luscious wines, the nature of the soil is of far less moment, such wines being grown

on every kind of soil, except that which produces the most valuable and rare dry growths. In the English colonies, and in the United States of America, not long ago covered with primeval forests, the soil, enriched by the autumnal spoils of ages, is too good for the vine, the fruit of which, for making good wine, differs so much from the character of fruit in general, when intended for the table.

The grapes are various that give out the more precious must. In Rousillon in France, the best wines are from the carignan, grenache, and mataro grape. The celebrated Rivesaltes wine is principally from the white macabeo, the muscat, and grenache blanche; the hermitage comes from the acyras or ciras grape, the roussette, and the marsan. The pineau blanco and pineau noir before mentioned produce the celebrated Clos Vougeot wine in Burgundy. In the Bordeaux wine district, the Graves, Barsac, and Sauterne, come from the white sauvignon, the semillon, the rochelin, blanc-doux, and premieras—all three white—and the black muscade. The best Spanish wines are the produce of the pedro ximenes grape, both at Malaga and Xeres. At Malaga and Grenada one half the plants are of this species; at Xeres, one-eighth; at Motril, four-fifths; and at Paxarete, one-fourth. The grape, giving fine wine in the North, may be productive of wine of very moderate merit in the South. In consequence every country, and even district of the same country, differs in the variety of the fruit prepared. This arises naturally from the circumstances of the temperature and soil affecting one species more than another, for which it may have less affinity. The growths are often mixed. Thus the marsan grape of itself gives a sweet wine, and the rousanne or roussette a dry, therefore they are mixed to prepare the white hermitage, for example. In Burgundy the black pineau is much used, as well as the chandeneu. In champagne the norien and pineau prevail, with some of the gamet and gibaudot. The black morillon, and the magdelaine, and the meunier, are early bearing species. The chasselas, supposed to have come from Cyprus, the cioutat or black grape of Corinth, the muscat noir, isabelle, verdet, and black muscade, the carbenet, violet, and corinth in France, the Uva del Rey, the mollar, the listan of Xeres, the larga and doradillo, with the moscatel gordo, are used in different proportions in some places in Spain, but one kind rarely or never alone. To enumerate and describe the five hundred and seventy species in the garden of the Luxembourg in France, could not enable a cultivator to discriminate what species would be best to adopt, so much depending upon site, climate, and annual temperature. The grenache blanche, for example, is only used in the district of Collioure in France. The Hungarian varieties also are numerous; but site and experience can alone determine, as elsewhere, the species most in accordance with the views of the cultivator in producing the best wine.

By a remarkable peculiarity, nature, and habit of the vine, it adapts itself to those parts of the country which are least fitted for the cultivation of the cerealia. Those vines which bear the best fruit for the finest dry wines, invariably grow on soils which would be unproductive

with respect to the food crops. Gravel, sand, volcanic debris, flint, and such like soils, are favorable to the growth of the vine, whilst rich, deep, warm, fat earth, and all rich lands, are unsuited.

The names of the different kinds of vine fruit in Hungary are so untranslatable in the West of Europe, and so far off, that they can hardly be identified with those of the West without inspection by qualified cultivators. Thus the Furmint is used in making the Tokay-Ausbruch in the Hegyalja; the Fejér-Szőllő of the same district; the Szemendrian or white Serbian grape; the Sár-Fejér or honey grape, believed by some to be the magdalen; the Balafant, the Rók-Szőllő or silver white; the Zapfner which, some contend, is identical with the Orleans of the Rhine; the Hárs-Levellő or linden-leaved; the purple Kadarka or real Hungarian; the Blue of the Banat, the Csoka, or Sloebblack, and a great variety of others, which it would be useless to name, are grown to produce the celebrated wines of Hungary.

The climate of Hungary is peculiar, and in extremes; so that, in some places, they are obliged to bury the stocks to keep them from the cold. The cellars are badly built in many places, and the casks too small, and new and unseasoned wood is continually adopted, spoiling the flavor of the wine. Marble store-vats are used in many places; one at Ofen will contain thirty-nine thousand gallons. That wines ripen best in a large volume, is proved in this district by these vats, or rather cisterns. The wines of the plains are inferior to those of the hills from the same description of fruit.

In Germany, the Riessberg, a small white grape; the Kleinberger, a very productive species; and the Orleans grape—make the more celebrated wines. The Orleans is the favorite at Rudesheim; but all the other wine-makers, except at that place, throughout the Rhinegau prefer the Riessberg. The grapes for the Joannisberger of the first class are carefully selected, and only a small quantity is ever made; about sixteen aums of thirty gallons each. The black pineau of Burgundy, and the teinturier are grown on the Rhine, as well as the chasselas. The traminer, white clivener, franken, gutadel, frülthoth, black clivener, and muscatelles, are cultivated to a considerable extent in Germany, and on the Moselle, where only the kinds adapted for a Northern class of wines ripen well. This may suffice to afford a faint idea of the great extent to which that portion of wine-making connected with agriculture must be carried, to embrace the entire subject over an extensive and ever varied field.

The grapes depending for perfect maturity upon their Northern or Southern latitude, the vintage takes place accordingly in September or October. Upon the excellence of the must rests the purity of the wine, and that depends much upon the season, the character and soil being the same. The utmost development of saccharine matter is watched until the fruit is ready to burst with ripeness, if all goes on well. The sun having dried up the dew, the work commences; the gathering being expedited most in warm weather, because the fermentation is then most active; and it is desirable to ferment at once the largest possible quantity of must.

The riper clusters are separated from the branches when the skin is thin, transparent, and not apt to break between the teeth; when the color is become deep, that is, when, if the grape be of a white sort, it becomes grey, or if red, from a violet hue appears black; when the stem is woody in fibre, losing its green color, and becoming brown like the main stock, the grape hanging loosely; lastly, when the grain gives way easily to the pressure in gathering, or when crushed, has a vinous odor. The bunches are gathered with great care, for which purpose scissors are commonly used, in order to shake the fruit as little as possible; as the ripe grapes are easily detached, and are bruised with the slightest fall. The baskets—Fig. 616—in which the bunches are placed are small; and the deposition in them takes

Fig. 616.



Osier baskets and mode of carrying the grapes to the press.

place with great care lest the fruit be injured. With large baskets the grapes are crushed; and the must is too often wasted, owing to the superincumbent weight. All the bad or green grapes must be taken off and put aside, as the unripe are apt to impart acid to the sound must. The grapes in different states of maturity are not to be mingled, because they cause an inequality in the fermentation of the must by their acidity, and consequently it is deteriorated. The baskets of osier of a peculiar make are carried to the press strapped on the backs of men, or in carriages. The backs of men, or even of animals, are preferred to carriages, because the motion is less. The stems of the clusters are cut short off. Some farmers take the grapes off the clusters, an operation in France denominated *egrappage*, but the practice is by no means uniform, nor is it universal.

The next part of the process is treading the grapes, or breaking them with machines, before they are set to ferment. This operation facilitates the fermentation. Square troughs are used, having holes in the bottom to admit of the must flowing out. The grapes are then trodden by men with sabots or wooden shoes, at the best, though an ancient, a clumsy, and not very agreeable operation. The must which escapes is thrown into the fermenting vat either with or without the muck, as may be required; and the same operation is repeated until the whole is trodden. The disengage-

ment of the coloring matter from the skins is mainly effected by this process, and no substitute would answer which did not obtain that object. The subsequent fermentation and the heat it produced would not alone obtain and fix the color; the skins must be broken. Several inventions have been exhibited and others carried into practice to meet an end so desirable. Of these machines at a reasonable cost, one is the invention of M. ACHER of Chartres, and has the recommendation of being among the cheapest. This machine is shown in Fig. 617. It does its work well, having the recommendation of the more experienced of the wine-

Fig. 617.



makers that it was capable of giving the must the utmost effect of which it was susceptible, before submitting the grapes to pressure. All were found to be equally and uniformly crushed—none escaping the action of the cylinder. By its use the fermentation proceeds in a more uniform manner, and the action of the press becomes more effectual. A, a hopper in which the grapes are placed; B, a cylinder, one metre in circumference, and sixty-five centimetres in length; it is armed with small nails; the heads large and flat, placed in curved or oblique lines on the cylinders, distant from each other five millimetres. This cylinder is placed beneath the hopper, to crush effectually all the grapes which descend to it. The cylinder is turned by a handle, D; E is a species of wooden flap armed at the lower edge with a series of teeth, perpendicular to the axis of the cylinder, disposed in such a manner as to play between the nail heads on the cylinder, and to crush all the fruit which approaches it; F, the vat which receives the must when crushed.

There is another French invention for the same purpose by a mechanic of Toulouse. It consists of two

horizontal cylinders, which act in the same mode as those of a laminating engine, not only by pressure, but by friction. It moves by means of two toothed wheels attached to one end of each cylinder. In order to communicate to one cylinder a movement more accelerated than that of its fellow, the diameter of each wheel as with its cylinder, is different. A handle is fixed to the end of the smaller cylinder. The larger is ten inches in diameter; the smaller six. These two cylinders are placed at the bottom of a hopper, in which the grapes are deposited. The whole is constructed over a cask or vat, five feet nine inches in diameter, or in length, if of a different form from that of a cask, and this receives the must. It is effective, and dispenses, equally as well as the machine of M. ACHER, with the old uncouth mode of treading out the fruit with sabots.

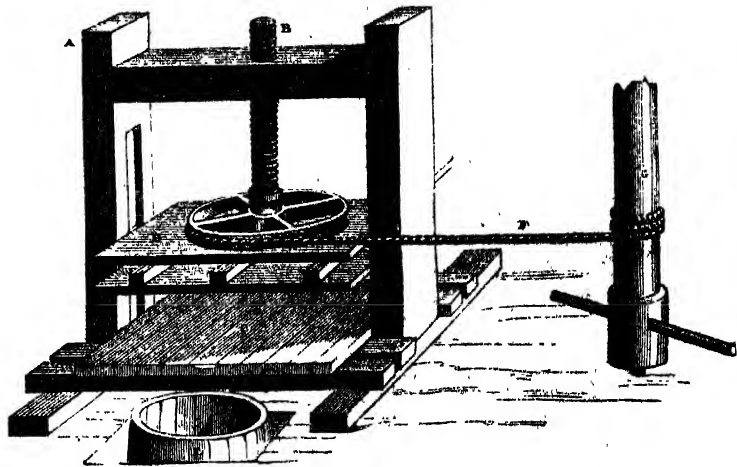
In order to prevent white wine from becoming colored, the red grapes are not trodden, because it would bruise the skins and discharge the coloring matter; but they are submitted to the press, as they arrive from the vine, and then taken to the vat, husks and all in some places; in others, the muck is reserved after the first pressure. The mode adopted in the use of the little press, which is directed rather to make a little choice than a large quantity of a middling class of wine, is as follows:—Planks are laid upon the bottom of the press, which is uneven, so that the must may run into one channel, and thence into a cask placed below the level of the floor of the press. The grapes are carefully piled on the *maye* or planks at the bottom of the press, other planks are laid upon the grapes, then several transverse beams of wood, and upon these the press is screwed down. The pressure at first is but slight, that there may be no waste of the must. The pressure is then increased until the utmost force of the screw is exerted, and the muck becomes as hard as a stone. The press is afterwards relaxed, the edges of the hardened mass cut square with an instrument for that purpose; and the cuttings being heaped upon the top, the screw is again applied, and the wine thus produced is called, *wine of the first cutting*. This pressing and cutting are repeated more than once. Finally, the muck is steeped in water, and again pressed, when a small wine is the produce, given to the laborers, called in France, *piquette*, and in Spain, *agua pié*.

The wine-press, an instrument as old as the days of the Israelitish lawgiver, is made in various modes in the same country. In Spain at this day presses are clumsy troughs, about eight feet square and a dozen inches deep, with a wooden screw in the centre. Into such a trough, in Andalusia, the grapes are carelessly flung, with a sprinkling of powdered gypsum in making white wine, to saturate the malic acid. The must is received in jars from holes in the trough, and carried thence to the butts. A bar or lever, of about five feet long, is used for turning the screw. The wine-press used in France for the hermitage wine, is a trough seven feet square, having an iron screw of vast power in the centre. This is turned by a wheel having projecting spokes for the workmen to pull it round. There is a stage round the press for the workmen to

stand upon. The grapes are built up in the trough as high as the screw will admit. The must flows from spouts in the sides, at the bottom of the trough. Wine of the first cutting is then taken. This press will make at once forty casks of wine, of fifty gallons each. The *murk* is generally distilled. In Burgundy, the trough or place for the grapes is twelve feet square, having a lever worked by a wooden screw. There is the *Bascule*, a large press requiring a dozen men to work it. The *Pressoir à étiquet*, moved by levers, or a horizontal wheel worked by four men; and the *Pressoir à coffre*, single and double. One in a vineyard in the Saone and Loire acts by percussion. This press is novel, and is the ingenious invention of M. RÉVELLON. The press before spoken of as used for making a small quantity of choice wine, in use in France, almost universally, though now somewhat improved, is here represented. In making white wine with red grapes, the want of care in the carriage of the fruit to the press, and the previous pressing, will sometimes cause the wine to assume a tinge of red, which, though slight, is very perceptible, and hence the epithet of *Partridge-eye* has been applied to it. Of course the quality of the wine is in no way altered by this circumstance. There is but one species of grape, the *tintilla*, which has a colored pulp. The grapes for the red wines thrown into the vat after being

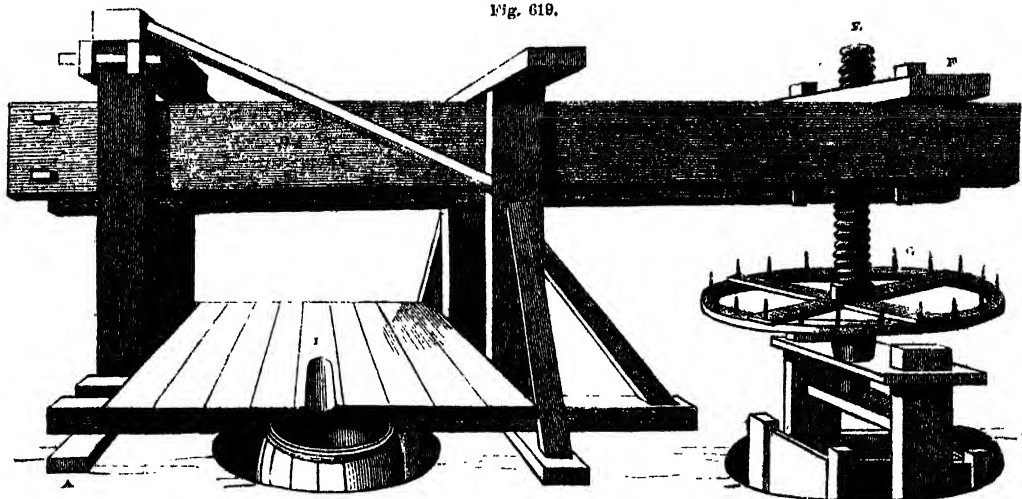
trodden, bruised, and evolving these colors before pressing, it becomes fixed by the heat of the fermentation. In some wines there is apt to be an astringency from the tannin in the stalks, attributable to the desire to preserve the tint; the stalks being acted upon by the heat of the wines, as well as the color in the skins.

Fig. 618.



Gypsum cannot be used in red wines without injuring the color. It is often esteemed preferable to carry out the vintage process in the hottest sunshine, where the external heat upon skins is found as effective as that imparted by retaining the *murk* during the fermentation. In Fig. 618, A is the press; B, the screw of iron; C, the *maye* or planks on which the grapes are placed; D, planks and blocks to support the grooved wheel on

Fig. 619.



which the rope F runs; E, the cask to receive the must; G, the capstan that turns the wheel and its screw.

The great press, which will make from twenty to thirty barrels of wine in four or five hours, was, in the last century, constructed in the following mode—Fig. 619—and is the most common of the older kind. A A, the base and supporters; C C, the cheeks; D D, great

beams of timber, sometimes four or six in number; E, the screw; F, the nut; G, the wheel turned by five or six men, holding the upright shaft; H, the cage, a square of timber lined with masonry, ten feet long and four and a half square on each side; I, the *maye* or platform on which the grapes are placed, as in the small press, with blocks and planks over them; L, a

grooved channel by which the wine runs into the vat *&c.* The cage will rise or sink into the pit; it is here shown ascending, and is in weight a couple of tons. Suspended at the end of the lever by means of its conjunction with the screw, it possesses immense power, increased according to the length of the lever, and thus it rapidly effects its object.

In some parts of the East the grapes are not pressed at all, but are beaten with wooden mallets on an inclined plane of marble, with a gutter at the bottom, which conveys the must into the cask or other receptacle.

On the sublimation of wines by the alembic, now the *still*, to which in recent times the term of distillation is applied, alcohol is separated. The name of this substance is derived from a *el*, more commonly *al*, the mark of the dative case in the Arabic language, joined to the word *ccoholmo*—in Spanish shortened to *colmo*—to rise to the top of anything; the invention having been brought into Spain by the Arabs.

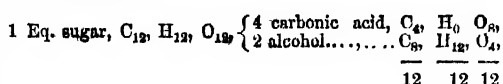
Hence, too, the word *alembic*—*alambique*. The meaning of the original name was retained in the verb to *sublimate*, *sublime*, or *raise up*, to the head of the chemical vessel or retort. Whether this substance was first sublimated or distilled from the must of the grape, or being of eastern origin, from the fruit of the date, or what other fruit, is uncertain; but in wine it is an important natural constituent. Distilled from the grape, it exhibits a superiority over that from every other substance, existing as it does in a variety of vegetal productions. The mode in which alcohol is formed or evolved by the natural process in the fermentation of the must of the grape, it is necessary to explain; its disengagement from other substances by the still having been already detailed under ALCOHOL.

The preparations for fermenting the must by which alcohol is formed, and the process of wine-making completed, are made with great care on the eve of the vintage. In France where the art is most perfect from superior science, the vats are in some places rubbed with over-ripe Portugal quinces; over those of stone elsewhere, a thin coating of whitewash is passed, to saturate the malic acid in the must. Instead of lime, the wooden vats are by some washed with warm water, and afterwards a little brandy is passed over the staves, while others rub them with decoctions of aromatic plants, salt water, or boiling must. These methods are all beneficial, except the use of the lime, which, without great care and judgment, is apt to detach itself and communicate a bad taste to the must, which is deposited in the vat at once from the receptacles at the press, with or without the *murk* according to the views of the maker.

The whole of the must being in the vat, the fermentation is the next and most important part of the process. It is divided into two stages; the first rapid, sensible, and tumultuous; the second slow, and of considerable duration. The second is often denominated insensible, though sometimes the escape of the carbonic gas is perceptible to the ear in close-covered vessels. The first demands the access of air to proceed promptly through its regular course, which, although rapid, has always a slight progression to the end

of the operation, which is at once discoverable by its being no longer turbid, and by the subsidence or depression of the head or *chapeau*—as the French denominate the scum, stems, and other substances, which float and form a crust upon the surface of the must, or rather of the wine, into which it has now become changed by the fermentative process—and the conversion of the sugar or glucose into alcohol. The reader will find the particulars of glucose described under STARCH and SUGAR, page 000.

One equivalent of anhydrous grape sugar is resolvable into four of carbonic acid and two of alcohol, whence this deduction:—



Sugar of starch and sugar of milk may be converted into sugar of grapes. In the sugar of the cane, and in that of grapes, oxygen and hydrogen are found in the same proportions as water. Grape-sugar, found also in honey and in most fruits, is the slowest of all sugars to undergo fermentation, during which the sugar is resolved as above into alcohol and carbonic acid by the presence, in only a slight degree, of a substance tending to set it in action. This substance results from the nitrogenous constituents of the grape-juice, and is named *diastase*. In making all natural wines, this substance found in the must comes into action spontaneously. Yeast is the product of decomposed gluten. This yeast added to a solution of pure sugar disappears; but when mixed with juices which contain gluten as well as sugar, it is reproduced by the decomposition of the sugar. Gluten is present in the wine-must undecomposed; decomposed in the state of yeast, it would ruin the flavor of the wine, and should never be used to ferment either grape or domestic wines.

The immediate presence of the fermenting agent at once causes chemical decomposition. Oxygen and hydrogen exist in grape-sugar in the same proportion as they are found in water. Carbonic gas is given out; and in consequence alcohol is formed from the sugar, while water is decomposed during the putrefaction of the gluten. A temperature of 65° is most congenial to vinous fermentation, during which the heat increases. At 60° the fermentation is perceptible, but exceedingly languid. There are instances where it has been known to rise as high as 97° or 98°. Thus the fermentation in warm weather is found to be considerably accelerated. When the weather is cold, boiling must has sometimes been thrown into the vat, and red hot-iron bars have been plunged into the must with the same object.

Fermentation in a very small active mass will communicate the principle to a large quantity at rest. The magnitude of the volume submitted to the operation shows, too, that large quantities proceed more satisfactorily than small, though, in the latter case, the alcoholic strength and aroma are better preserved. After the lowering or fall of the crust or head, the sign of the first fermentation being over, the must is covered up from the air; no more opening being left than is sufficient to suffer the carbonic gas to make its escape.

But there are other substances formed in wine besides those already mentioned—some of which amount to little more than perceptible traces, and these are not found in all wines. Their quantity and even presence will depend upon the nature of the soil in which the vine was grown which produced them, and the cold or heat of the season; for in cold summers the fruit is acid. Starch, gum, albumen, gluten, extractive or coloring matter, bitartrate of potassa, malic, tannic, gallic, and a little citric acid, traces of tartrate of lime, of alumina, and potassa, sulphate of potassa, chlorides of sodium and of potassium, and in some, perhaps traceable in all wines, there are racemates and paratartrates. Racemic or paratartratic acid was discovered by M. KESTNER, and mistaken by him for oxalic acid. It is a modification of tartaric acid, and distinct in its nature. It was first thought to be peculiar to the grapes of the Vosges, and was called *acide de Vosges*. This acid is obtained from a solution, containing as well tartaric acid. The crystals are an oblique prism, with a rhomboid base; those of tartaric acid have a rectangular base. Its formula, as given by GREGORY, is $2\text{HO}, \text{C}_6\text{H}_6\text{O}_{12}$.

There is also an odorous principle called oil of wine, which is sweet, quite neutral, and is formed during fermentation, and obtainable from alcohol by pouring two and a half parts of sulphuric acid on one part of anhydrous alcohol. It boils at 536° , and has a specific weight of 1.133. It has a flavor somewhat resembling peppermint, and imparts a vinous smell to the wine newly formed. The salts procured from this oil are identical with the sulphovinates procured from sulphuric acid and alcohol. There is also a lighter species of oil of wine, specific gravity = 0.917 to 0.920, resembling olive oil. It is composed of $\text{C}_{16}\text{H}_{16}$, or very nearly the proportions of olefiant gas.

Climate makes an important difference in the component parts of the wine-must, as well in the acid as in the sugar dissolved. Hot climates produce a must rich in sugar; but this difference does not appear to affect the extent of the nitrogenous matter in the must, for it seems to be all expended in some wines before the sugar is converted into alcohol; and a part remaining undecomposed, it produces the thick sweet wines of the South. In colder regions the nitrogenous matter and sugar being alike expended, and the wine as it were balanced in regard to these principles, as in some German wines, dry long-enduring wines are produced. When the gluten is in excess, the wine, not preservable with facility, is soon converted into acetic acid if great care be not taken. It absorbs oxygen, and the oxidation is communicated to the alcohol. This oxidation may be prevented, and the conversion into acetic acid arrested, by the addition of a small quantity of sulphuric acid. Fermentation has been ascribed to the growth of fungi and infusoria; but much more evidence must be given before this can be received as a fact.

To return to practical vinification—the method of making the produce of the vine in fermentation differs with the climate, season, nature of the fruit, temperature of the vineyard, soil, mode of culture and fancy of the proprietor, who is often guided by local custom. In some places the wine is not suffered to remain in the

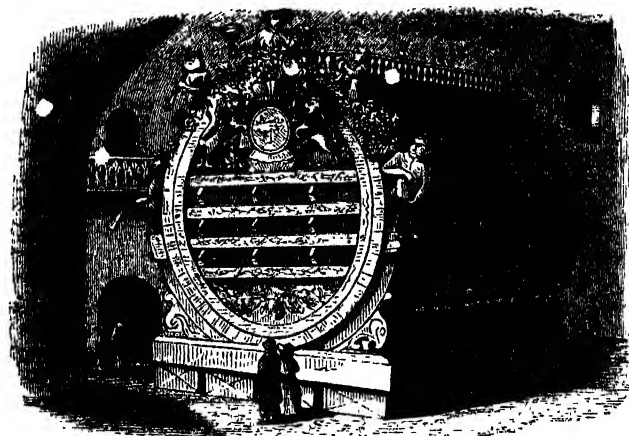
vat more than from thirty-six to forty hours. Near Lyons in France, it remains six or eight days, and in general from ten to twelve. In the South-west of France, it remains from twenty-five to forty; and at Narbonne, it is carried up to seventy days. When the farmer is asked how, the fermentation being over and the wine at the temperature of the atmosphere, he suffers it to remain still in contact with the stalks and stems to clear itself in the vat; he replies, It is the custom, and, if warned again of acidity through the breakage of the scum or crust, he answers he only acts according to usage—it should be *ignorance*. It is true the crust is almost always compact; but it is a hazard unless the saccharine principle be abundant, and the albuminous matter all taken up.

Vinous fermentation in general takes place under the free admission of air. An attempt was made by a Madame GERVAIS of Montpellier at the close of the last century, to introduce fermentation in close vessels. The idea was not new. M. DE LA PLOMBANIE, M. PORTA, a Neapolitan, and the German chemist, BECKER, at the commencement of the seventeenth century, had recommended the same process. But the admission of the atmospheric air is indispensable to the operation. A considerable noise was made about the invention, which, it was supposed, would preserve the aroma, and prevent the escape of alcohol. M. DELAVEAU instituted some experiments with great care under a fermentation for nineteen days, when it was found that the return from the vat had the most agreeable flavor; that the wine distilled afforded a spirit only equal to that fermented the usual way; the latter if anything yielding the largest quantity of alcohol. The vat with the invention gave sixteen and a half alcohol at a temperature of $80^\circ.5$; the vat with a simple cover, generally used in the South, sixteen and three-eighths; and that not covered at all, sixteen and an eighth. It was thought that the color of the red wines was somewhat deepened by the invention; but neither the aroma nor the vinosity was increased, nor was the invention considered of moment, so as to come into general adoption. Long experience had proved the efficacy of the old mode, and chemistry could find no ground to impugn it in a scientific sense. The strength of the wine, besides that which may be denominated alcohol, or rather its endurance, is in some degree due to the stems and the tannin it contains; but though used in port and some similar second-class red wines, they are excluded from the delicate red wines of France, though adopted in some of the white, while they are also excluded from the Rhine wines. In Spain the wine, having in Andalusia a great enduring power, is left to ferment in the butts, into which it is taken in the *mosto* or must state. The bungs are left open, and the wine and froth thrown up in the fermentation are poured back into the barrel to feed the wine, as they phrase it. This causes a renewal of the fermentation at every atmospheric change, and even on any accidental motion of the cask. In the month of March after the vintage, for the first time, the wine is racked. The advantage of large vats has made no way with the Spaniards. It might be best, *quien sabe*, but he keeps to the old track. The delicate and choice French

wines would be ruined by such a mode of conducting the fermentative process.

On the Rhine the fermentation, after the must is ready made from picked fruit, the stalks put aside, and the different pressings set apart, takes place in casks, to preserve the aroma. The wine is then repeatedly racked, and placed in tuns holding about eight hogsheds and a half, where it remains for many years to acquire perfection. Some of the older tuns, in which the wine no doubt mellow best, are those locally denominated *fuders*, and will contain three hundred and fifty tuns. The celebrated tun of HEIDELBERG has long been renowned. It is thirty-one feet long by twenty-one high, and holds one hundred and fifty fuders, or six hundred hogsheds. It was built at Heidelberg in 1663, as a successor to one which held only a hundred and thirty-two. There was once a larger tun at Dresden, shown in Fig. 620, which held three thousand seven hundred and nine hogsheds.

Fig 620.



It will be interesting to the reader to know the strength of the must at different periods. The specific gravity of the Pedro Ximenes must at San Lucar, after two days' exposure to the sun in September, was 1.092. At Paxarete in October, its must, after four days' exposure, was 1.121. The must of the Mantno-Castillan grape at San Lucar in September was 1.069. The black mollat grape at San Lucar gave a must in the middle of September of 1.064; and at Paxarete, the last day of the same month, 1.089. At Chipiona, in the middle of September, the muscatel called gordo-blanco, a large white variety, after three days' exposure to the sun, gave 1.089; at the end of the month 1.096; and in October a specific gravity of 1.114. At San Lucar, in the middle of September, the white Temprana grape gave about 1.075; but, on three days' exposure to the sun, the specific gravity was 1.114. This last grape at San Lucar is cultivated to the extent of nineteen-twentieths of the vine lands. In the Paxarete, Ximenes, Muscat, and Tintilla wines, it enters largely.

In Hungary are made the celebrated rich liqueur wines *Essences*, *Austruchs*, and *Maslas*, *vins cuits*, and wines suppressed in fermentation mingled with

other substances, and so long noted for their excellence; the grapes are carried in sacks, for the making, as those of Szamorodny, for example. They are treated in fermentation in the ordinary manner. The fruit or the essence, already obtained without pressure, and over-ripe, is carefully picked upon a large table, called a sorting-table, and placed in a cool vessel covered over. It is then put into a large vat, where men with cleanly washed feet, under a superintendent, tread them into a paste. This grape paste is then placed in a second vat, and covered over. New must of the common wine of the country is then poured upon it, the quantity of which used determines the quality of the wine, or wine *de liqueur*, according to the owner's pleasure. Sometimes two measures, or four, five, or six of the essence are added to ten of the common wine. The proportion of six to ten is rarely exceeded. The wine and paste are then mixed, and left for a couple of days, or for three, if the temperature be low, stirring the mass frequently.

This thick must is then conveyed to the press, a slight pressure producing the richest kind; it is next conveyed into a cask, and thus becomes the celebrated Tokay Ausbruch, or flowing syrup. It is skimmed while fermenting, and strained into casks. It has a fine aroma, but never becomes very bright. It is soft and oily on the palate. There are two species, one containing generally sixty-one parts of essence, and eighty-five of wine; and the other called *maslas*, having sixty-one parts of essence to a hundred and sixty-nine of wine. The best sells for twelve pounds sterling the dozen. The fermenting and purifying proceed together. That of 1811 was celebrated, the fermentation having been perfect. There is besides a great variety of wine in Hungary, but all of a peculiar character.

The greatest care in manipulation, and the most scientific methods in the treatment of wine, have been tried in France, and the result has been the production of the finest wines in the world. The removal of the wine from the vat to the cask is there as carefully regarded as the work of fermentation. The casks are all made ready at the same time as the vats. If the wood of which they are made is new, they will not fail to communicate an astringency and bitterness to the wine. To prevent this, the casks are repeatedly washed with cold water, and then with hot, in which peach leaves and salt are infused. They are repeatedly shaken while the fluid is hot, and then are left so that the wood may absorb them, and they may penetrate into the pores of the timber. The casks are now emptied, and boiling hot must, to the extent of two or three quarts, is introduced. The bungs are put in, the casks shaken, and then left to cool. Some use only hot wine in place of the above substances. If the casks are old, they scrape off the tartar that lines the staves, and wash them with hot water and must, or wine. If they have contracted an ill smell, or show the least mark of decay, they are burned at once, because, in

spite of all that can be done, sooner or later the bad effects will appear. Casks should be sulphured, if the least suspicion attach to them, by the introduction of a match at the bung. Such casks are generally made of oak staves, but some prefer beech. They bear different names in different parts of France, as *barrique* at Bordeaux, *botte* at Lyons, *tun*, and *pipe*, *et cetera*, in other places. When large, they are called *muids*, and very large ones *foudres*. Some have proposed vases of clay varnished, but they are considered porous, and cannot be easily conveyed from place to place.

The wine being fermented, the duration of the fermentation, depending upon the state of the temperature, the amount of sugar and similar things, to be decided upon observation and according to the season, the wine is drawn off into the cask. Some of the finest Burgundies, called wines *de primeur*, only remain in the vat from six to ten hours. The rest in the vat is only important on account of the color. If the skins were sufficiently broken, so that the coloring principle stands in no need of the action caused by the tumultuous fermentation to bring it out, the fermentation with the fruit and its grains being often more mischievous than useful, it is omitted. If the skins are sufficiently bruised and torn, when the fruit is trodden, to give out all the coloring matter, it is not considered wise to suffer the must to enter the vat after pressing.

The drawing off the wine into the cask at the exact moment is a point of great importance. The crust or chapeau having fallen, and active fermentation ceased to the eye, all being perfectly quiet, the examination with a wine glass, the taste, color, and odor, except tested by experience, are often fallacious. Taste and smell are so different in individuals that there is much uncertainty upon the time when it is best to operate. The heat generated in fermentation depends mainly upon the quantity of glucose or grape sugar which has entered into the spirituous state. No fixed rule exists. It is frequently found that the maximum of heat is attained after twenty-one hours of fermentation in one case, and in another after ten, while the wine is not really perfected perhaps for twenty hours longer, so that the thermometer is no reliable guide as to the vinification. Something to determine the fact of the vinification mechanically, was long considered a desideratum by the French producers. There were the differences of climate, soil, and species of fruit to be considered. An attempt was made to ascertain this point by means of a vertical rod, marked with a scale to show the elevation and depression of the fluid. It was placed in the middle of the vat to indicate the depression of the must after its previous repulsion by the fluid, and that the time thus indicated should be that of drawing off the wine from the vat. This was found to be correct in seasons when the sugar was abundant, and then the moment of the retrogradation of the must was the best for emptying the vat. In wet seasons, on the other hand, the indicator did not seem to answer, but the inventor had little doubt of success in establishing a scale to indicate the time sought in different seasons when the temperature varied; but he was unable to carry out his experiments beyond three seasons, having been compelled to become an exile.

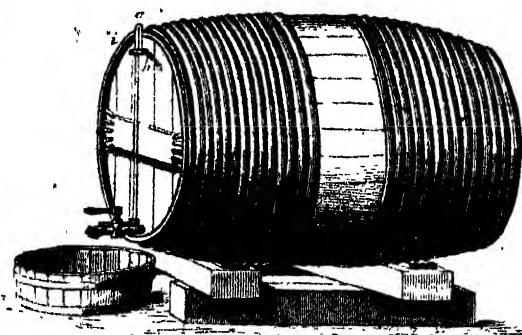
In drawing off the vat it is necessary, before commencing, to take away with great care, by the use of a wooden shovel, that part of the head or crust which, having contracted acidity by exposure to the air, if it broke and became mingled with the must beneath would spoil the whole mass. The must drawn off, the murk remaining in the vat is pressed for the wine called that of the press, which is equal in quality to that which has been drawn from the vat without pressure. The wines thus made are called that of the first, second, and third vatting, as before stated. The first taken is the most spirituous, and the last the harshest, sharpest, and deepest-colored. The second pressing holds a middle quality. The residue of the murk is used for the manufacture of verdigris, for the food of cattle, for vine-dressing, or for nourishing pigeons, which greedily devour it. These later wines of the press are sometimes mingled with that of the vat, an indefensible practice, because the wine from the vat will often by such a mixture lose its own peculiar delicacy.

The wine being in cask is, in the pure wine countries, directly placed in the cellar. The cellars vary in different countries. In Spain those of the Xeres district are of great size, to the extent of three hundred English feet long by above two hundred broad. Four thousand casks of wine are arranged in similar cellars in tiers, and are called *soleras*. The wines of different seasons are mingled in these, so that one will contain some of each vintage for thirty seasons. The wine is fermented in the butts, the bung-holes being left open without endangering the wine; nor is the cellar temperature much regarded, such is the firmness of the wine. In Valladolid the cellars are deep in the earth, like mines, with huts over them. In France the cellar is an object of peculiar care, the exquisitely delicate wines of the first-class in that country demanding great attention as to safe-keeping in their highest and most perfect state. The best and favorite cellars are held to be such as are situated under uninhabited buildings, as is observable in the places most noted for the culture of the vine, having a Northern exposure, and fifty or sixty feet deep, according to the dryness or the humidity of the soil. A uniform degree of moderate humidity is best. A cellar too damp causes the decay of the barrel staves, or covers them with a mouldiness which communicates a bad taste to the wine. If a cellar be too dry it makes the staves of the casks shrink, and the wine is wasted by leakage. The air should be admitted only by small openings, facing the North, made near the roof or vault, and susceptible of being closed when the weather is too hot or too cold. The vault or roof should be as solid and thick as possible, in order that no external concussions should be communicated to the wine. The soil above the vaulted roof should be united and well beaten down, and that part designed to receive the bottled wine should be covered with sand or fine fresh-water gravel.

The casks should be placed in a position perfectly horizontal, upon wooden beams six or seven inches square, supported by others transverse. Wedges should be forced under the casks on each side to keep them steady, and neither the casks nor their supports should

touch the wall of the cellar. If the casks are not set perfectly level, the wine lees will collect in the back part and prevent the wine flowing clear out of the cask the usual way. If the front be too much raised, the lees will come to it when the cask is elevated behind, in order to draw off the last of the wine, and thus stop the passage. The lees should settle in the belly or hollow of the staves, which will take place when the casks are kept perfectly horizontal with wedges, as shown in Fig. 621. Attached to the cask here given is

Fig. 621.



an air tube, to illustrate the mode adopted in some parts of France to prevent the admission of air over the wine, so apt to cause acidity.

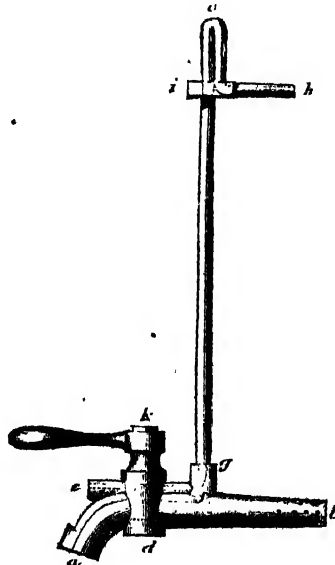
The tube or canal, *abc*, is of the common form, except that the bottom of the tap at *d* is pierced with two apertures, of which the lower serves for the passage of the liquor, and the other corresponds with tube *efgch*, by which air is introduced into the tube to replace the liquid drawn out. The result is that it suffices to turn the tap, *k*, to cause the liquid to run; and to shut it, that all communication with the exterior air shall be cut off. It is evident that when the tap is turned the wine will run out, and that the exterior air will replace that wanting by the tube *efgch*, and that on shutting, *k*, the pressure of the air will cease with the running of the wine. The tube is carried higher than is necessary, that the wine may not enter the tube at *h*, and may have the least possible distance to the surface of the wine, and thus prevent agitation. The tube at *h*, and the tap at *b*, both enter the cask. When the cask is to be all drawn off at once, of course such an application is superfluous, but it is invaluable where small quantities are taken in draft.

No garden stuff, green wood, flowers, fruits, or similar substances must be permitted in any cellar in which wine is kept, because the gas disengaged from them promotes ascendency. The wine being deposited in the cellar, the insensible fermentation commences but too sensibly if that in the vat was imperfect. Carbonic acid gas still makes its escape, augmenting the volume of the wine, and forcing itself out at the bung in froth or scum. Hence it is necessary to take care that the casks are not quite filled when they leave the vat. At least two inches' space is left, and the bung driven home to prevent the slightest entrance of the atmospheric air. A gimlet hole is made on the upper side

of the cask, and stopped with a peg or *fausset*, in order to let the carbonic gas escape. Some wine-makers place in the bung-hole a linen cloth, filled or covered with sand or vine leaves pressed down with a tile.

When this fermentation ceases, and the wine has sunk down, the cask must be filled up and hermetically closed with linen round the bung. The operation of filling up by the bung is denominated *ullage*. In some places ullage is performed every day for the first month, every five days for the second, and every eight until the wine is racked. The celebrated Hermitage wine is thus treated. At Bordeaux ullage is performed on the eighth day—filling up exactly every ten days during the first month, and then once a month to the time of racking. In other places, if the collars are dry, twice in two months; if humid, every three months. Ullage is performed in fine weather with wine fully equal in quality to that in the cask. The cellars are to be visited daily to guard against accidents, such as a leak in a stave from a wormhole, injury from commotion in carriage, mouldiness of the staves if the cellar be too damp, or shrinking of the staves or heads in those which are too dry. The wine from time to time is tasted, to ascertain its state and remedy any perceptible mischief. When ullage is neglected, a white mouldiness, called the *Flower*, is observed on the surface of the wine—a certain forerunner of acetous degeneration. The air is at once forced out, the nozzle of a bellows being introduced for that purpose, and then it is agi

Fig. 622.



tated. A sulphur match is introduced, and the bung inserted. The cask is struck from below, to raise any concealed air bubbles to the surface, and to carry all the mouldiness possible to the bung-hole, which is filled so as to make the wine run over, and these efforts are continued until no vestige of the *Flower* appears. The wine in the cellar is observed to work much when the vine commences to bud, and when the fruit ripens,

which BUFFON attributes to the changes in the juice of the vine. FABBONI and other authorities have stated that this phenomenon is only observable when the particles of the wine have not been separated by a sufficient quantity of alcohol—in other words, when the glucose was not equal to the subjugation of the gluten, and the other constituents were not in due proportion. This fermentation is prevented by the use of sulphuric acid, sulphate of lime, mercurial oxides, additional alcohol, camphor, ice, and water at the boiling point. When the wine is still, it is perfected, and only deposits its lees, consisting of portions of the pulp of the fruit, of the coloring matter, and of the tartar, which last is found crystallized on the interior of the staves of the cask.

The next process is that of racking, undertaken to clear the wine of the substances which tend, by mixing anew with the wine, to form a fermentation. It is an operation not generally performed at a stated time. In some places it is done in December, after the vintage, when the wine is required to be moved; if not, it is done annually, generally in the months of February or March. In some countries this operation is performed twice the first year, in spring and at the end of September; in others, at the end of December and middle of May—the first during a sharp frost. Much, however, depends upon the quality of the wine. Generous wines may rest upon the lees three or four months, and be only racked once in two years, but in general they are separated from their lees before the first equinox of the spring succeeding the vintage. There are times when, on the other hand, in lieu of racking, it becomes necessary to recombine the lees with the wine, in order to establish a fermentation which may ameliorate them and promote their maturity. This operation being of importance, it is necessary to describe. The smallest inadvertence will produce, in conducting it, the acetic action, the tendency to which, the moment it is perceived, must be met by racking at once, and moving it to the coldest place possible, and before racking it must be fined. The weather most proper is that which is dry and clear.

The wine is drawn off carefully that it be not disturbed, and when the cask is stouped for the last of the liquor, it must be done with great care and judgment by hands accustomed to the operation. The Beaune wines in France are generally racked by the introduction of an instrument into the cask well calculated to draw off the fluid without disturbance, and these wines are always remarkably fine. At Condrieu on the Rhone, the wine is racked eight days after it is made, and before the end of the month it is fined, then racked anew, sometimes twice or thrice at an interval of fifteen or twenty days, in order to procure the limpidity so desirable. Wines not cleared sufficiently by racking are fined, the substances used for the purpose being isinglass and whites of eggs. The isinglass is cut up and steeped in a little wine, until it becomes viscid and softened. It is then thrown into the cask. The wine is afterwards strongly agitated. The quantity of finings used is about five drachms to every five or six hundred litres or quarts of wine. The whites of eggs, preferred in some places, are well beaten up in a little wine, poured into the cask, and left to rest for ten or fifteen

days, when the wine is racked during the first Northerly wind. From six to ten fresh eggs are used for every twenty-two gallons imperial. Various substances have been applied for the purpose, as gum-arabic, hartshorn, calcined flint, rice, milk, and starch, but none produce the desired effect so promptly as isinglass or the white of the egg. Ordinary wines lose their acidity by fining, and the finer classes increase their brilliancy and clearness.

Wine is sulphured at times, in other words, impregnated with sulphurous gas, by burning sulphur matches over it. These consist of a roll of linen or cotton an inch and a half broad, and six or seven long, dipped in melted sulphur, to which powdered leaves of aromatic plants are sometimes added. Those made at Strasburg are noted. The match is suspended from the bung-hole by a wire, and being lighted, the bung is closed. The air within dilates and escapes through the smallest opening. The operation contributes greatly to the preservation of the wine, though some say it injures the color of red wines. Those who object to it throw a little brandy into the cask, to which they set fire with a bit of lighted string, and while it is burning close up the bung, leaving only just air enough to keep up combustion. In other cases a wine is made; the fermentation is arrested, and the must placed in a cask until it is a quarter filled, and a number of sulphur matches are burned over it. The cask is then closed and strongly agitated, until no gas escapes on opening the bung. More must is then added, and the agitation repeated, until the cask is full. This must never ferments, has a sweet taste, smells strongly of sulphur, and when a certain quantity of alcohol—of the strength *trois-six*—is added, a wine named *wine of Calabria* is the product, employed principally to give strength and sweetness to wines deficient in those qualities.

MULDER states that wine, stored in wooden casks, loses water, whether mixed with alcohol or not. But if evaporation affects the contents of the cask, the loss must be repaired, otherwise the action of the air would turn the wine acerb, and convert the alcohol into acetic acid. It is chiefly water which is evaporated, and its loss is made up by adding wine. All the constituents of wine, with the exception of water, are hereby increased, and the wine becomes not only stronger, but better flavored. The vinous components being more concentrated, are better able to act chemically upon each other, and this, *per se*, would account for the improvement of the wine. Here one has a general statement of the causes upon which the difference between new wine and that which has been stored in casks mainly depends. But the change is carried still further. The concentration of the wine, or rather the diminution of water, which is continually replaced by wine, causes a constant augmentation of tartaric acid in the wine. Wines which are poor in sugar may easily become too pour, and all wines cannot, therefore, undergo this process. The quantity of tartar in the wine is not increased; for, being insoluble in alcohol, the continual increase of alcohol precipitates it. That which is augmented is tartaric acid, which is soluble in alcohol, and insoluble in cream of tartar.

Madeira, and such like wines, are sent to warm countries to improve. MULDER had Madeira which had been seven times in cask to the East Indies and back, and truly, says he, *such nectar was unknown to the gods of the ancients*. The drier the atmosphere is which surrounds the casks, the greater will be the evaporation. To avoid this, care must be taken to prevent draughts, and to keep the air of the wine stores or cellars moist.

Wines remain in wood different periods, according to their qualities, and while thus resting are in a state of improvement. Some repose only three or four years before bottling. Tender, delicate, light wines gain little in the bottle, while strong spirituous ones preserve well in that state, and to a certain point improve. In bottling fine wines the bottles and corks should be new; the smallest defect in the latter determining their rejection. The French dip the corks and the bottle necks in a composition differently colored, to distinguish the wine, and thus shield the external part of the cork and a little of the neck of the bottle with it from the action of the air. This composition is made for three hundred bottles with two pounds nine ounces of rosin, half that quantity of Burgundy pitch, a fourth of yellow wax, and a small quantity of red mastic melted together, so as to form a liquid mass in which the corked necks of the bottles are dipped. In the cellar the bottles should be placed horizontally, to keep the corks always wet. Fine fresh-water gravel or sand is their best bed, and keeps the wine cool, but sea-sand from the salt in it, is pernicious. Sawdust only answers for coarse wines.

Wines of fine quality can only be mixed with others of a like quality to render them more generous, or to have a larger quantity of one particular flavor. It is a robbery or a great abuse to sell wine mixed in any other way for a genuine growth. Wines of Bordeaux are sometimes strengthened with hermitage or wine of Cahors, and are known as Medoc wines; but they are genuine and of good quality. Wines are liable to alteration and to degenerate. Such are loss of color, bitterness, acidity, tasting of old, of the wood, of musk, mouldiness, and what the French call *graise*, milkiness or cloudiness. To amend the last they use pure tartaric acid, taking care that little of the carbonic gas given out shall escape from the cask. This acid is composed of 2HO , $\text{C}_8\text{H}_4\text{O}_{10}$, and is found in a good many fruits beside the grape. The acid is mingled with sugar and introduced hot into the cask, which is closed and agitated for five or six minutes. Two days after, the wine is fined in the ordinary way. The carbonic gas is the agent of the cure. Wine is sometimes passed over fresh lees as a remedy for the same disease; and then racking is had recourse to afterwards. Acidity generally attacks wine which wants body. This never amends itself, but proceeds to the acetic state if left alone. Taken at the earliest moment, it is transferred into a cask impregnated with sulphur by the means before described; and different modes are employed for the cure of the mischief. Some dissolve honey, others liquorice, in the wine. Acetate of magnesia, bone gelatin, and similar substances are used; but the best mode of cure is to pass the wine over the relics in

the vat, after the vintage product for the year has been drawn off. Even then it should be drunk early, for it cannot be trusted over another season. Oftentimes the acetous fermentation has already commenced, and there is no resource but to leave it to the vinegar-manufacturer. The bitterness in wine will sometimes become cured by itself when in bottle. It takes place in old wine. If not cured by passing the wine over fresh lees or mingling new with that attacked, it should be reserved for the still. Loss of color generally happens to the deepest-tinctured wines approaching age, arising from a species of fermentation for which recourse is had to purified tartar reduced to a fine powder and mingled. If unsuccessful, it must be mixed with a younger growth. The taste of old and musk—the latter thought to be caused by insects—the depositions of different wines, and the taste of the wood, add to the multiform cares of the wine-grower and admit of a variety of applications for cures not always successful. There is a wide road here for chemical investigation and experiment yet untrodden, as there is also to determine exactly those constituents which give to certain wines their delicate aroma and flavor. The odor which is peculiar to all wines must, to a certain extent, be ascribed to cranthic ether.—*Vide ALCOMOL*, vol. i., page 105.—The volatile substance existing in wine, which imparts to it, conjointly with cranthic ether, its vinous fragrantcy, is alcohol. Other beautiful volatile compounds have been detected in wine, but there is much yet to be discovered. To what substance does a fine Saunterne owe its most peculiar but magnificent bouquet? Acetic ether appears in most, perhaps in all, aromatic wines, and is developed in them by time. The adulterators of wine are well acquainted with this fact, and know how to make use of it. Acetic ether is largely sold for this purpose, and added in proportionably small quantities to wines which are not aromatic, to improve their fragrantcy. Two or three drops are ample for a bottle of wine. The reader is here referred to the article ETHER, vol. i., page 832, for full particulars with regard to the properties, *et cetera*, of the delicate ether existing in wine and spirits.

Besides the wines denominated sweet and dry, prepared from the fruit in the mode, and their difference arising from causes already stated, there are prepared wines in which the must is concentrated by evaporating a portion of the aqueous part, a very ancient custom wherever wine of the usual kind is made, called in France *vins cuits*, in Italy *vino cotto*, and in Spain, from the Arabic, *arrope*. The wine is boiled down to a third part, being skimmed of its froth, and sometimes, while boiling, aromatic substances are infused, or else it is used in its unperfumed state for strengthening other wines.

Dry and sweet wines, or wines of *liqueur*, are distinguished principally by the saccharine principle, in sweet wine, not being all converted into alcohol, the glucose surpassing the gluten in proportion, and the change being in consequence only partially effected. Such are the wines of Malaga, Rivesaltes, and Frontignan, and the wines from the rich muscatel grape more especially. Straw wines are also sweet wines, made of grapes for some months suspended upon straw bands

and afterwards pressed and fermented. The produce is about a sixth only of that obtained at the vintage. It has a strong rich flavor of the dried raisin. There is also a wine called *de Grenier* in France, made in nearly the same manner, and a sweet white styled *de Gamde*.

Another wine of a very distinct character and of two kinds, one drier than the other, is procured by suppressing the fermentation, in other words, retaining the carbonic gas to a considerable extent. This species comprehends the wines of Champagne and their unworthy imitations, called sparkling Burgundies, Moselles, and others, all managed in the same mode. There is a genuine wine at Arbois of the same kind, or *mousseaux*, as the French term it, made in a mode somewhat different. The crust or chapeau is allowed to rise and settle over the must, as in the common mode of fermentation, so far as that the fermentation is not visible and no further, in order that the wine may be racked off in a clear state, being watched day and night for the period when bubbles of carbonic gas begin to appear on the surface. It is then racked into a vat and remains until a second crust or scum forms, and this is repeated until the wine is perfectly limpid. It is now placed in casks carefully kept filled. The bungs are daily examined in case of starting, that the cask may be filled up immediately. The air is excluded when the fermentation ceases, racked again in January or the following month, and in March fined and bottled. The corks being wired, the wine is deposited in a cellar of the requisite temperature.

To return to the more celebrated wines of Champagne, distinguished as still, creaming, and sparkling wines, or *mousseaux*, *crémans*, and *non-mousseaux*, of which the two last are most in esteem. The best froth very slightly, as Sillery; and the finest, called *vin du roi*, not at all. These wines come from the banks of the Marne and constitute a unique class. They are made for the most part of the blackest grapes, gathered with care, and only the sound fruit used. The grapes are carried to the press in baskets, covered up from the sun, and placed on the press with as little motion as possible. The must is poured into a vat for a term of from six to fifteen hours, that the dregs may be deposited. As soon as ever fermentation appears, the wine is transferred to the cask. The product of the first pressing is set aside as the choicest. The second pressing, or the wine of the *first cutting*, lightly colored and spirituous, partly composes the effervescing wines. The wine of the third pressing is kept for giving strength to the ordinary red wine of the country. This wine is put into bottles in March or April. At Rheims, on the other hand, they bottle the Sillery in January, although at the risk of its imbibing the effervescing quality. It having been thought advantageous to secure champagne of a uniform quality, which it was difficult to do from its being put into small casks; tuns holding twelve thousand litres were a few years ago introduced at Rheims by a German house, and the advantage of their use became evident.

The next step is to procure bottles of great strength, free of air bubbles, of the exact size, and without a flaw. The number required to bottle the effervescing wines in the department of the Marne is enormous; eight hundred

and sixty-six thousand gallons having been bottled in one season in the arrondissement of Epernay alone. In March or April the bottling commences. If done earlier, the breakage would be greater, fifteen per cent. being the ordinary loss. In the fermentation the carbonic gas not being allowed to form sufficiently or fully develop itself in the cask, it is quickly reproduced in the bottle; the saccharine principle renews its progress towards alcohol; and if the latter be sufficient to prevent the decay of the wine, the quality is good. This wine does not effervesce in uniform times. Some kinds will do so in a fortnight; others will be months before the signs appear. One wine will require a change of temperature for the purpose, and must be brought up nearer to the surface of the ground, if the cellar be deep. Another kind will not exhibit itself until the month of August, and a third kind only at the time the owner's patience is almost exhausted, when it will appear unexpectedly. If a wine shows no sign the first year, it is mingled the next year with new wine known to possess the effervescing principle. Nothing is certain; the cellars, their soil and depth, the air-holes, the difference of the place of growth—all seem to have an inexplicable effect upon the operation.

The bottles, carefully cleaned by rinsing and shotting, are placed in the working shop or *atelier*. The barrel-heads are bored, and a small brass pipe with a gauze-strainer, is inserted. The bottles are filled so as to allow about two inches clear space between the cork and the wine. This space diminishes, while the carbonic gas is generating; and the fractured bottles show that the expansion of the fluid has primarily quite filled the void. A workman who fills the bottles passes them on the right hand side to the principal operator, who is seated upon a stool, with a little table before him covered with sheet-lead, and about as high as his knees. He inspects the allotted space between the cork and the wine, regulates it exactly, selects a cork, moistens it, introduces it into the bottle, and strikes it so hard two or three times with a wooden mallet, that an observer wonders it is not broken by the violence of the blows; and yet fracture this way is rare from the attention paid to the management of the bottle at the same moment. This workman then passes the corked bottle to his right, where a third workman, seated precisely in the same manner, crosses the cork with pack-thread, and ties it strongly. He then passes it to a fourth workman who wires the bottle, cuts the wire, and hands it to a youth who places the bottles upright in the form of a parallelogram, so that they can be counted in a moment. The daily labor is calculated at a drawing of from sixteen hundred to seventeen hundred bottles. The best cellars of Epernay are those of M. MOET, and the bottles run in a pile from end to end, six feet high, and are carried down in osier baskets, having in each twenty-five cases for the bottles. Two men carry them by leather belts drawn through the handles of the basket. Slopes are prepared beneath in cement to carry away the wine from the broken bottles in the piles, with reservoirs to collect it. The bottles are placed head to tail on laths, the corks one way the reverse of the other.

The piles are very solid; and any one of the bottles, with the neck to the rear of the pile, can be easily with-

drawn in order to examine its state, and see if the carbonic gas is developed. If not, all must be got into the proper state, cost what it may. When a bottle is drawn from a pile, and kept in a horizontal position, a deposition is generally observable called the *griffe*, or claw, from its branching appearance. Before a bottle breaks, the vacancy below the cork disappears by the expansion of the carbonic acid, which generally occurs in July or August, when commonly from four to ten per cent. of breakage is experienced; too often the mischief reaches from thirty to forty. Sometimes, of the same wine in the same part of the cellar, one pile will remain with the gas undeveloped, while the other shows no sign of effervescence. A current of air will sometimes make the wine effervesce furiously. Thus great expenses are incurred, not only by breakage, but in attempts to excite the carbonic development. The loss by the breakage is often not equal to that of correcting the inertness of the wine, independently of the trouble. If not exceeding ten per cent. in breakage, the maker is satisfied. If it is deemed necessary to take down the pile, the bottles are set upon their bottoms for a longer or shorter time, and this causes a difference in the quality of the wine. At one time it is removed into a deeper cellar; or, lastly, the bottles are uncorked to disengage the gas, and clear the space under the cork. When the carbonic gas is furious in its development, the wine is wasted in large quantities. The wine of the broken bottles becomes scattered among the sound, or fragments remain which contain wine, and become acid and even putrid. The gutters become infected, and in the air of the cellar new principles of fermentation ensue. In August workmen have been obliged, owing to the fragments of glass projected from the piles, to put on wire masks, and entering the cellar to throw cold water over the wine. The breakage ceases in the month of September. In October the piles are *lifted*; the bottles being taken down one by one, putting aside those broken, and placing on their bottoms those in which, on examining the necks, the corks and sealing seem to have moved. Some bottles are found to have lost a portion of their contents, and the loss must be repaired. The deposition, too, must be removed. For this purpose the bottles are placed in an inclined position of about 25°, and are shaken two or three times a day, to detach the sediment, for ten or fifteen days successively. Planks with holes in them receive three or four thousand bottles together, keeping them in the right slope. The workmen then, with considerable dexterity, get all the deposition into the neck of the bottle, near the cork, the wine being perfectly clear. Every bottle is then taken by the bottom, kept carefully reversed, and the wire and twine being broken—the bottle resting on the workman's knees—the cork is dextrously withdrawn, so as to permit the gas to explode, and carry the deposition with it. An index is then introduced into the neck to measure how high the wine should ascend, and the deficiency is made good with wine that has before undergone the operation. The bottle is then a second time corked and wired. If the wine remain long in the cellar afterwards, before it is sold, it is submitted to a second clearance or *dégorgement* of a similar kind about a fortnight before it is sent away; the

process to the last being laborious and expensive. These wines do not admit of being mingled with any but those of their own growth, and those genuine are rarely mingled at all. Grey champagne is made by treading the wine slightly before pressing, and rose-colored by a longer treading; but the latter is generally wine of inferior quality. In good cellars these wines will retain their excellence for twenty, and even as far as thirty years, in the last case imbibing only a slight degree of bitterness. The temperature of the cellars in which the wine is kept, is best at about 53° almost unvaryingly. The receptacles at Epernay are excavations in the calcareous rock, thirty-five feet below the surface of the ground. The creaming and still wines keep the best; those very frothy are most liable to change, and are really the least worthy of the class.

The finest red wines in the world are those of Burgundy, in the district called the Côte d'Or. They are produced principally from the grape called the *Pineau*. From twenty to thirty hours in the vat are sufficient to convert the glucose into alcohol, and then in two or three years they are fit for drinking. If moved in the cask in the least as they deposit, they are apt to spoil. On this account the finer kinds are only removed in bottle, and should be kept with great care. When old they take an amber color. In England the first classes of these wines and their proper management are unknown; the second classes alone being imported as the first, the coarse taste of the English palate in wine preventing the discovery of the difference. The finer wines are all produced in the districts of Nuits and Vosne; of these the Romanée-conti and the Chambertin are among the more celebrated. The white wines of the same district are not so well known or esteemed as the red. In the Mont Racher wine, a celebrated growth, made near Beaune, occurs one of those extraordinary phenomena in wine which no scientific investigation has succeeded in explaining. Three kinds of wine are made of fruit grown on the same land, so contiguous as only to be separated by a footpath, having the same exposure, the soil appearing the same, as well as the species of vine; yet the last brings only one-third the price of the first. The whole ground is about thirty-seven hectares, of which the most prized is but seven, the next quality eighteen, and the third twelve. The wine of the first fruit sells at twelve hundred francs, the second six hundred, and the third four hundred.

The climate of Italy so congenial to the vine, produces no wines of export much valued, owing to the ill management of the vintage. No attention is paid to sorting the grapes; ripe and unripe are thrown into the vat together. Nicety and even cleanliness are neglected. The grapes are trodden and thrown into a vat, where the must remains fourteen days in a state of continued fermentation until the wine is spoiled. Sometimes the must is left exposed to the air for a month together, and the wine, ill-managed, has no reputation. In Tuscany more attention is paid to the process than in other parts of the country, and very palatable wine is made, but with little improvement in the process. The Montepulciano is a sweet wine long

noted there. This wine is racked repeatedly for two months after it is made, but the fermentation is often continued until the wine has begun to contract acidity before it is removed into the cask. In Naples they make a sweet wine called *lacryma Christi*, but the process is as careless as in other parts of Italy—in fact there are four or five wines of that name, some pretty good, others execrable. In Sicily the Mazzara wines, and the sweet wines of Syracuse, are made with little care; but English capital and some pains having been bestowed on the Marsala and Etna wines, they are exported to England, according to custom, brandied to excess to save care in their management, or, as the phrase is, to fortify them. The Marsala wine, well treated, is sound and good, and made in the fine climate of Sicily with French science, might still be greatly improved.

The Greek islands produce wine of various kinds, but mostly muscadines. In Cyprus the grapes are not suffered to lie too numerously on the stock. They are of a rich purple, with a thin skin. The vintage begins at the end of August. For the celebrated wine of the Commandery, the fruit is placed on covered floors called *punai*, and spread out with care in a bed of eighteen inches thick, where the grapes remain until the seeds or grains are ready to drop from them. They are then carefully lifted with wooden shovels and carried to rooms paved with marble, or covered with a cement equally compact. These floors are made of a gentle slope. The grapes are bruised with a wooden mallet, and pressed in little presses denominated *putitisi*; the must, which is very thick, flowing into a vessel on the lower side of the floor. This vessel is emptied, when full, into small vases, and in these conveyed into baked earthen vessels with acute bases, like the ancient amphoræ. In these the wine is left forty days to ferment, in some places with the vat covered while in that state. This wine, if taken while in a state of fermentation, causes severe colic pains, to prevent which it is filtered through bags of vine ashes, but when thus treated it never attains the perfection desired. When the fermentation has ceased, the wine is shut up from the air with covers of baked earth, and has already put on a lighter color than before. These vessels are either coated internally with pitch, or varnished the instant they leave the potter's hand. If varnished, the composition consists of a boiling liquid in which turpentine and pitch are mingled with vine ashes, goat's hair, and fine sand; this effectually closes the pores, and never falls off. The art of making these vessels belongs to the remotest antiquity. They hold from twenty to thirty barrels each and in them the lees are deposited, which are called *mana*. When removed, leathern bags are adopted, pitched on the inside, and detrimental to the wine, which does not for many years lose the disagreeable flavor. The cellars, in so hot a climate as Cyprus, are all above the ground; little light is admitted, and the aspect disregarded. This famous wine was named from the Commander of the Knights Templars, to whom the district once belonged. The Commandery wine resembles the Italian wine of Chianti in color. From a red it changes to a yellowish hue the first year, fines itself as it grows old, and in nine or ten years takes nearly the same appearance as the sweet wines

of the South of Europe. The dregs are thick, and supposed to aid the sining. When brought from the country to the town and put into casks, it is always in such as have less remaining, in which it is left for a year. Whether ullage is attended to or not, it makes no difference in regard to the excellence of the wine, for sometimes a cask is left not three-fourths filled. It is sold at the vineyard by the load of sixteen jars, each containing five Florenee bottles. The wine is warranted good by the seller until the August after the vintage. It is generally exported in casks of three hundred and fifty bottles each. Only about ten thousand jars are now produced. When poured into a glass, if good in quality, the particles adhere like oil to the sides. Cold injures it; in a Northern climate it must be placed before a fire. The lees are always treasured up, and are often in color a mixture of black, red, and yellow, though generally like Spanish snuff. Those wines and the muscadines of Cyprus are different. The wines of the Greek islands are mingled with rosin to impart durability, and are very disagreeable to the taste in consequence. The wine of the Crimea, at least that called *kokour*, is fermented coarser than in Cyprus. The vats in many places are only pits dug in the ground, plastered with a composition. The Shiraz wine of Persia is made of trodden grapes, fermented in jars of glazed pottery agitated briskly; it is then bottled for sale.

The wine of Portugal, forced upon the people of England in 1703, by rendering the duty on that wine a third less than on the produce of other countries, drove out many fine wines, of which there was a great variety before, and forced an inferior article upon the public, under the absurd idea that Portugal would take English woollens in return, as if all trades were not an exchange of goods. The effect was to drive all variety in wine out of the country, and make Englishmen take an inferior article. At first the wine came in its natural state, but was afterwards sophisticated and brandied. Efforts were too soon made to control the market by limiting the supply, and rendering the wine nearly of a uniform quality. After the Portugal wine monopoly of 1756 was established, brandy was added, and increased until, in recent times, no less than from twenty to twenty-four gallons per pipe are flung into the wine during and after fermentation. In its natural state this wine is not permitted to come to England. The growth is stunted because the export is limited by a privileged company, which creates an artificial scarcity. The wine is adulterated with a mixture called *gerapiga*, two-thirds must, and one-third spirits 20° above proof, with elderberry juice and sweetening matter, and is sanctioned by the English Government, though a gross adulteration, being admitted here as a spirit to carry out a fraud. This medley is used only in preparing wines for England. The pure wine is seldom allowed to be exported, although good and enduring, since by this doctoring there is an equality of class established that defies seasons or bad crops. The grapes are gathered when mature almost to shrivelling. They are from the bastardo, sousao, and alvarelhao vines. The fruit is trodden with the stalks, and remains during the fermentation, which continues about seventy hours, in vats

containing from ten to twenty pipes each, and while fermenting, brandy is added. The wine is racked in February, and sent to the company's or merchant's cellars in Oporto. More brandy is added to the wine intended for exportation, and again in a year, when shipped, more is thrown into a wine having in its natural state, on the average, amply sufficient alcohol to insure endurance with common care. It now carries a strong odor of brandy, and must remain a dozen years until the wine, or rather brandy-wine, is sufficiently subdued in alcohol to be drunk, when it bears little resemblance to the genuine wine, having become dull, and its freshness and aroma having disappeared. The consequence of the delay often is, that while ameliorating the extractive and coloring matter of the original, if not of the elderberry, becomes deposited, the wine tawny, and the flavor without a trace of the real unadulterated article. The perverseness of usage is become in a century so much in harmony, on the part of the consumer, with the merchant's notions of brandy being necessary to preserve a wine with sufficient alcohol by nature, that a genuine and honest port wine would now be regarded as worth little, on the plea of coldness, except to real connoisseurs. At first, in 1730, only about two gallons were added to a pipe. In 1754 the practice was styled *diabolical* of checking the fermentation in this mode of *fretting* in spirit, which it was fondly imagined immediately assimilated with the natural alcohol of the wine. The Portuguese charged the English at Oporto with commencing this base practice, and making wine seem *like liquid fire in the stomach*. It is observed by one authority that, in preparing these wines, it resembled throwing into one large vat all the red wines of a country of different growths, to produce an immense quantity of second-class wine. There are excellent wines thus mismanaged. The Collares port, Bucellas, Lisbon, and other wines made in the customary manner, bespeak that there is no fault except in the management. One wine-grower purchased elderberries a few years ago to the extent of four hundred pounds in a season; and one hundred and twenty pipes of adulterated must have in one year been landed in London from Oporto, to mingle with Portugal red wine in England, and doctor or strengthen what was too weak. Science can discover nothing worthy of record in the manipulation of the Oporto wines.

The vines of Madeira, now nearly destroyed by the *oidium*, or wine disease, were a remarkably fine class. They were planted in a volcanic soil, a mixture of red and yellow tufa, called *sabro* and *pedro molle*. A light clayey earth and volcanic cinders were intermingled. The husbandry was rude; the vines planted in trellises. The vintage took place in September, and the wine of the highest quality, called *pingo*, was that which flowed from the treading alone. The wine was pressed to the fourth pressing in a trough-press, with a lever like that of a cider press. The grapes were sorted and the *mosto*, or must, fermented in pipes. Gypsum was sprinkled on the grapes. The must was agitated during the fermentation, which exceeded forty days in duration. The wine was mellowed in stoves, kept at a temperature of 80° or 90°. A voyage to the East or West Indies was always preferable for

ripening the wine, when it could be accomplished. There was once a very agreeable cordial wine, made in Madeira, by checking the fermentation and adding brandy to the must. The *sercial* is the product of the hock grape, never drunk under seven years old, and then not in perfection. There were once three kinds of malmsey, from as many different kinds of grapes, in these islands. That from the cadel grape was the best. The tinte resembled new Burgundy, but was less harsh; it was drunk under three years old, at which age it lost its color, and took that of old Madeira. It had an agreeable aroma. Wines of Madeira were sometimes ripened by plunging them into a trench of fermenting horse dung. The bottles were corked, and thus the wine attained, in a few months, the maturity of a voyage at sea. This, however, may be doubted; because, at sea, not only a particular temperature, but a considerable agitation is kept up. A pipe of Madeira, attached to the beam of a steam-engine, in the warm engine-house, is said to have produced the effect desired. Madeira is, or rather was, in perfection in twenty years. The vine disease has suddenly ruined this far-famed wine, and the unfortunate people of the island that produced it. A very fine sample of this wine the Editor received from Mr. J. R. HURTON of Liverpool—a nutty flavor, and yielded 15.69 per cent. of alcohol.

The wines of Spain are quite distinct from those of Portugal, as well as of France. Many of them are superior of their class, and of the white wines in particular; they constitute the largest quantity of any single foreign wine, red or white, entered in England for home consumption. The wines of Spain, except those of Andalusia, in which much British capital is invested, are carelessly made; but their firmness, just alcohol, resistance to what would ruin very delicate growths in the North, arising from a warm and genial climate, prevent their merits from passing unappreciated. The fine red wine of La Mancha, the Val de Penas, was, until recently, carried about only in pitched skins on the backs of mules. The great exports of wine are from Cadiz and Malaga. The sherry is made near the town of Xeres de la Frontera, nine miles from Port St. Mary's, across the harbor of Cadiz. The grapes are left on the tree until they are shrivelled by the sun's heat, and when plucked remain exposed to it some time before they are pressed. The fermentation is generally left to take care of itself, with all the acum it forms; and yet the wine is so fine that very rarely mischief occurs to it. Racked after the vintage, and constantly under the eyes of the agents or principals of foreign houses, resident on the spot, the management is carefully scrutinized. The grapes here are sprinkled with powdered gypsum, once locally termed *giesso* or *jess*. The must ferments in the cask left entirely to itself. It is racked in March. The casks are left open in all temperatures, and sometimes in the open air without ill effect. A good cellar, so named in France or the North, is not thought of moment here. While fermenting, the bungs are so open as to allow the easy escape of the carbonic gas. Ropiness, dreaded elsewhere under such treatment, is very rarely observed. The natural color of the pure wine is pale; the colored are from a

blending with a dark wine called *arropé*, made by boiling down six butts of must to one, keeping the liquid continually stirred and the surface skimmed, avoiding the accident of burning, on which account the process is slowly conducted. When thick enough, the fire is gradually withdrawn, so that the fluid may cool without any injury from chill. It is then mingled in different proportions with the pale wines, thus constituting colored and brown sherry. Nothing foreign is ever mingled with those wines, except a couple of bottles of very good brandy upon their exportation. The sherry, denominated *amontillado*, is a drier wine than the common sherry, and is often the result of accident. To this wine no addition but of its own class can be made without spoiling, not even a glass of brandy. A sample of this pure wine the Editor received from the highly respectable house of Messrs. CHILLINGWORTH and SON of London. It had a superb flavor, and only contained 11.50 per cent. of alcohol—proving it to be a pure wine. Of a hundred butts from the same vineyard, some will be *amontillado* without it being possible to discover the cause. Thus the constituent parts in *amontillado*, if supposed exactly balanced, raised the question, Why should this occur in a small portion only of a larger quantity? When it is made, the grapes are plucked a week or two before those for the other wine, but the treatment is just the same. The wines that pass for sherry in England in taverns, are generally made-up wines, or good mingled with inferior or low wines. Another species of wine which may come under the sherry denomination is that called *Manzanilla*—light, delicate, and straw-colored; it is not always liked at first. It derives its name, some say, from a village near Seville, and as others suppose, from *Manzanilla*, a small apple. Neither surmise is correct. *Manzanilla* is the camomile, and there is something of the taste of that plant in its flavor. It is delicate and will admit of no foreign mixture. The dryness shows that the glucose and vegetal extract are well balanced in its fermentation. It is produced from the *Rustan* grape. The wines of Malaga are of ancient date, and the vines are grown near sugar canes, the only spot in Europe where the latter are found. The *bastardo* grape makes the sweet wine. The must is conveyed from the press, half fermented, to the merchants' stores in sheepskins, and the wines are sent to all parts of the world unbranded, except to England. The mountain wine is made in Malaga, and one species is called wine of pears, because that fruit is steeped in it. There is also a cherry wine, called *guindas*, made there. It is much flavored with the cherries. There are many excellent wines in the interior of Spain, but made unpalatable from bad management in the fermentation, exemplifying the Spanish proverb—*To cry wine and sell vinegar*.

The dry wines of Xeres and Malaga, as well as those of Teneriffe, were formerly called *sacks*, and the sweet also. In 1598, in Hakluyt, it is stated by one who resided eight years at Teneriffe, that it produced three kinds of wine—Canary, Malvasia, and Verdona, which may all go under the denomination of *sack*. The wine of different ages is mingled in Andalusia, the newest with old of the purest quality.

The wines of Andalusia are rarely sulphured, from

fear of the taste remaining, and on account of English prejudices. Some Englishmen complained of the taste where sulphur had never been used. Here the stalks, and often not even the skins of the grapes, are suffered to ferment in the must. The wines are white, and color is not wanted. In France the stalks are left in the must according to the nature of the season; if fine they remain. In Spain the glucose abounds in the grape; and were it not for the practice of leaving the scum on the wine, and even returning it under the idea of supporting the wine, none would ever become acid. The system of large vats, so friendly to a beneficial fermentation, has not been tried there. Nor is it necessary; for in their present state they enter into the largest consumption in the English market. The better wines of Southern Spain yield nearly a fifth part of alcohol on distillation, and the quality so returned is excellent, and only inferior to the best of France. The *tintilla* wine of Rota is a red of Andalusia, generally taken as a cordial from its extreme richness. In Alicante a wine is made from the same kind of grape, which holds much tannin, precipitating a species of animal gelatin. It is of an orange-red color, rough, and somewhat bitter. In Catalonia the wines are generally good, and of the red species. *Vinaroza* and *Benicarlo* produce good red wines, much of which passes for port in England, either mingled with it or flavored, so as to secure the similitude. This wine is of a wholesome quality. The malmsey of Sitges is white. In Arragon, the wine of Carinena is the best. A muscadine named *Fuencaral*, is made near Madrid, and a fine dessert wine at Peralta in Navarre.

The wines of Spain have the ascendancy in England, perhaps from their freedom from acidity, owing in part to their treatment in the vat with gypsum, to which must be added their own natural tendency and strength, as seen on their exposure to the atmosphere under circumstances in which the wines of other countries would run rapidly into the acetous state. Wines which contain much of the gluten, are more susceptible of the acetous fermentation than those in which it is more sparingly dispensed; and the latter is the case with the wines of the Xeres district, in which little or none remains after fermentation, without half the trouble in racking and fining which is bestowed on other wines. There can be no doubt, this refers to the white wines of that part of Spain alone when the spirituous fermentation has ceased. The little brandy added, and often none at all, to the best wines of Xeres, as is evidenced in the beautiful sample of Messrs. CHILLINGWORTH above referred to, shows how well their constituent parts are adapted for preservation, compared with some ports and oftentimes their twenty gallons of artificial brandy. It is only to the meagre wines of the country—mingled with a little of the good, and called *low sherries*—that brandy is added, to render the wine more agreeable to the corrupted taste of the English public, which is thus to be satisfied with brandy and wine in a state of mixture, in place of brandy and water. The intemperate use of pure wine when indulged, is never followed by those disorders so common and fatal in the use of the favorite dull fiery wines of the generality of persons in England, particularly in the class called hepatic affections. Brisk,

lively, natural wine, is totally distinct in its action on the human frame from that of the brandy wines medicated for a perverted taste. The effect of pure wine in excess is transient; of brandied wine it need not be detailed. The Editor is convinced, from investigations and analyses, that there is no more necessity to add brandy to port than sulphuric acid to vinegar. If the liquid be well fermented, sound, and good, any addition is pernicious and wicked.

There is no just ground for believing that brandy will prevent acetous fermentation, although the common notion is that it will do so. It is incredible how far custom goes in effecting error, and preventing its correction, often indeed irremediably. A merchant of good sense desired to have sent him, even if smuggled out of Oporto, half a dozen pipes of port-wine without a drop of brandy. His correspondent would only send him one in reply to the order, being certain *that without brandy it would not keep*. The wine came and remained good in the cellar for years till drunk out. The Oporto merchant did not know, that for forty or fifty years after the Northern treaty of 1703, little or no brandy was put into a wine of a very full body, nor that Sir EDWARD BARRY complained in 1773 of these wines becoming too hot. It was not until the end of the last century that they were so fully deluged in artificial spirit—introduced at first under the idea of their preservation, and continued, perhaps increased, by fevered stomachs, which called for deep colored, sweet, and strong; in other words, for more elderberry, sugar, and alcohol.

Brandy in a small quantity will not stop the acetous fermentation in vinegar, for it becomes itself acetified, and makes the vinegar stronger. That one-seventeenth part alcohol should succeed in so doing, as some experimentalists aver, is met by other facts; for acetous fermentation is very easily produced in wine containing an eighth part of alcohol. It is still possible that alcohol added in a sufficient quantity may suspend or retard the fermentation, owing, perhaps, to its not mixing with the natural alcohol of the wine. Chemistry has not yet made this point clear; but it would seem that the general notion of vinous preservation through alcohol, unless in a ruinous quantity, as it is applied in port, sometimes to more than a fifth of its bulk, is very erroneous. The Editor has found port sold in some of the hotels with *thirty-five* per cent. of brandy!

The fact is, that the usage at first, from whatever cause, gave a desire for strong wine in England; and there was the advantage that the growths of bad and good years flung into large vats, and well mingled with brandy, gave a product of that middle-class wine artificially so made, which paid better than a little choice at a high price, and a good deal at a very low figure. It must be observed, too, that in most Northern countries, except France and those yet more to the South, there is a continued craving after alcoholic strength. This has been the case in all ages of the world. The Englishman has his wine medicated until spoiled with brandy; the Persians infuse poppies and similar things for the same end. There is ever a craving for increased stimulants, which, not found in the wine itself, must be added. The Greeks and Romans medicated

their wines, or rather perfumed them with various substances. The holy scriptures have left evidence of this, even in the earliest times of the Jews. The alcohol in wine placed there by nature seems to have its parts separated, and to be rendered comparatively innocuous compared to that added unnaturally; and, in the former case, will not readily intoxicate like alcohol mingled with water, milk, and similar liquids. The Jews had no knowledge of alcohol or the still, and endeavored to render their wines more stimulating by their deterioration, as is done at present another way. They had a general term for fermented liquids of all kinds—*shekhar*; but the words, *strong drink* or *mixed wine* are denounced, meaning wine with spices, and stimulating aromatic drugs. *Jahin* or *Yagin*—the *j* is pronounced as *t*—is the term for wine in general; *sobhe* is sometimes used figuratively for the same liquor, and *tirosh* for new wine. But *shekhar* means strong and medicated wine, of which honey was one ingredient, as well as spices and herbs. In the time of AUGUSTUS CÆSAR honey was mingled with his wine, and exposed to the sun, perhaps fermented in it; and as honey contains grape-sugar, it would necessarily strengthen the alcoholic principle, if there remained any gluten, for the emperor could drink no more than a pint of it at a time. Alcohol is formed by nature in every human stomach to a certain extent, according to an eminent chemist, and so far must be congenial to it. The reasonable use of natural wine is often highly advantageous. Discoveries in relation to the combination of alcohol with wine are yet to be made, but it remains certain that it is one of the vinous elementary constituents. Medical men will designate the difference between the effect of wine with its alcohol on the human economy, and the effect of alcohol combined with water. The ebriety produced by champagne in which carbonic gas and alcohol are combined, and that produced by pure claret or chambertin with port and madeira, are obvious to all who move in society where good wines are taken. The effects so lively and airy of the one, with the dull sedative state produced by the last, a blunted quiescent state not easily disturbed, but when disturbed not easily appeasable—indicate different effects from causes, no satisfactory definition of which has yet been obtained.

There has been much dispute regarding the alcoholic strength of wines. There is no reason whatever to dissent from BRANDE's analysis of a considerable variety, made with great care, and there is little difficulty in making the test correctly enough; but the utility is only comparative, because the particular wine to which the test is applied must be taken for itself alone, according to the nature and produce of the grape for the year of the vintage, and not for a succession of years, nor for the same sorts generally; and the like holds good with all the constituent parts, and those slight traces of foreign substances, from differences of soil and plant, and little more, continually perceptible in wines. The same vines for two successive years will not bear fruit so exactly similar, as that some difference shall not be detected in the wine, and in the different proportions of its alcohol. The nature of the season in the same vineyard, and often under similar circumstances, will cause unaccountable changes. A warm year causes the

saccharine principle to be abundant, and, yielding more alcohol, gives a stronger wine, as is evidenced upon distillation. Nor is this natural effect more an impediment to classing wines by their alcoholic strength, than that of throwing in brandy, as in Portugal, during fermentation. By the wine being artificially brandied is prevented an accurate knowledge of its alcoholic strength, in the kind most commonly used in the British islands, as no two samples can be expected to show the same result. Thus it arose that the analysis of Dr. BRANDE was wrongfully censured, because it did not appear to be exactly what everybody supposed.

The Editor is of opinion that no port wine contains naturally more than fifteen per cent. of spirit—four or five per cent. are afterwards added to insure the wine keeping for years, in which time the artificial spirit becomes perfectly blended and mellowed in the wine.

The simplest method of ascertaining the amount of alcohol contained in wine is to distil the spirit from the wine, determining its specific gravity and quantity, and compare it with the quantity of wine taken; of course one of the first things to be considered, is how much wine to distil. The Editor takes generally one-third, and determines the alcoholic contents from it. If, for example, in the distillate thirty-three parts out of a hundred are composed of alcohol, the quantity of alcohol in the wine will be 11 per cent. for $\frac{33}{3} = 11$.

In the case of strong wines it is advisable to distil even more than a third, especially if a glass retort and water bath are used. Let the distillation be continued till at least half has passed over. If the density of the distillate is such as to yield twenty-five per cent. of alcohol, then $\frac{25}{2} = 12.5$ per cent. of alcohol.

In strong new wines, undecomposed sugar and vegetal extractive matter may cause the evolution of more alcohol during the insensible fermentation. It may be presumed, notwithstanding, that if the quantity of alcohol in any wine exceed twenty per cent. it has been added artificially. All bottled wines, which improve at all, become sweeter, and old wines always appear to have gained in sugar. A very generous wine of the Drôme, in France, will afford a third of its weight in the brandy of commerce; in the department of the Herault there will not be more than a fourth part; in the Côte d'Or about an eighth of what is called prime brandy; in the department of the Charente, a still, charged with two hundred and forty litres of wine, yields from twenty-four to twenty-six of spirit, or about a tenth of the volume of the wine, and a little more in quantity of the second-class spirit; in the department of the Gard, from the same quantity of wine, forty litres of prime spirit, and about the same quantity of the second class. From these products it is easy to approximate to correctness in regard to the amount of spirit in wine, and thus it is seen that one-third spirit is given in first and second brandy of the Gard, while there is often a third distillation, which is not included.

In France it is found necessary to accommodate the Northern palate, by adding ten per cent. to the wines supplied to that part of Europe.

A tale, that BRANDE had only tested adulterated

wines palmed off upon him for genuine, was as silly as spiteful. Dr. BRANDE took the wines as he found them in the hands of the merchant, in a state awaiting consumption; and no rival examination showed a greater difference than might be expected to exist on all similar trials. The reader must bear in mind that it is nearly half a century since Professor BRANDE analysed the wines referred to. The Editor has always considered the per centage of alcohol given in genuine port to be too high, and this seems to be corroborated by the fact that samples of port, vintages 1820—1834, *et cetera*, kindly forwarded to him by Messrs. CHILLINGWORTH for experimental purposes, never gave more than *eighteen per cent. of pure spirit*. The 1820 had a specific gravity of .9945, and the distillate .9740 = 18.01 of alcohol; and the 1834 had a density of 1.0163, and the distillate .9723 = 18.99 of alcohol. Extractive matter in 1820 was 5.140, and in the 1834, 5.976 per cent. There is too frequently a disposition prevalent to cavil at scientific men and their statements because they are novel, or do not chime in with preconceived notions. The nature of the combination of the natural alcohol with wines is not now understood, but its effects just noted are undeniable. This combination cannot be supposed to be any other than one of those secrets, the discovery of which science will one day lay open. Annexed are the results of BRANDE, PROUT, and others, as to the alcohol contained in the well-known wines in common usage.

PORTUGUESE WINES.	Alcohol in 100 parts.	Specific gravity.	Analyst.
Port,.....	25.83 ..	— ..	Brande.
Do.	24.89 ..	— ..	Do.
Do.	23.71 ..	— ..	Do.
Do.	23.39 ..	— ..	Do.
Do.	22.30 ..	— ..	Do.
Do.	21.40 ..	— ..	Do.
Do.	19.00 ..	— ..	Do.
Vinho de Ramo,.....	15.62 ..	— ..	Prout.
Do. average,.....	22.96 ..	— ..	Brande.
Do. average,.....	20.64 ..	0.9890 ..	Prout.
Do. weakest,.....	14.97 ..	— ..	Christison.
Do. strongest,.....	17.10 ..	— ..	Do.
Vinho de Ramo, mean of seven samples,.....	16.20 ..	— ..	Do.
White port,.....	14.97 ..	— ..	Do.
Colares,.....	19.75 ..	— ..	Brande.
Carcavellos,.....	19.20 ..	— ..	Do.
Do.	18.10 ..	— ..	Do.
Do. average,.....	18.65 ..	— ..	Do.
Lisbon,.....	18.94 ..	— ..	Do.
Do. dry,.....	16.14 ..	— ..	Christison.
Bucellas,.....	18.49 ..	— ..	Brande.
Vidonia,.....	19.25 ..	— ..	Do.

SPANISH.

Sherry,.....	16.81 ..	— ..	Brande.
Do.	19.83 ..	— ..	Do.
Do.	18.79 ..	— ..	Do.
Do.	18.25 ..	— ..	Do.
Do.	21.34 ..	0.9752 ..	Do.
Do. average,.....	17.17 ..	— ..	Do.
Sherry, very old,.....	23.86 ..	— ..	Prout.
Do. weakest,.....	13.98 ..	— ..	Christison.
Do. strongest,.....	16.17 ..	— ..	Do.
Mean of thirteen kinds,.....	15.37 ..	— ..	Do.
Do. long kept and East Indian,.....	14.72 ..	— ..	Do.
Mean of Madre de Xeres,.....	16.90 ..	— ..	Do.
Amontillado,.....	12.63 ..	— ..	Do.
Tint,.....	18.30 ..	— ..	Brande.
Alba Flora,.....	17.26 ..	— ..	Do.
Malaga, 1863,.....	18.94 ..	— ..	Do.
Do.	17.26 ..	— ..	Do.

MADEIRA ISLANDS, ET CETERA.		Alcohol in 100 parts.	Specific gravity.	Analyst.
Madeira,	24.42	—	—	Brande.
Do.	23.98	—	—	Do.
Do.	19.24	—	—	Do.
Do. average,	22.27	—	—	Do.
Do. Sercial,	27.40	—	—	Do.
Do. do.	15.45	—	—	Christison.
East India, in cask,	16.96	—	—	Do.
Do. weakest,	14.09	—	—	Do.
West India, do.,	21.20	0.9908	—	Prout.
Red Madeira,	22.30	—	—	Brande.
Do.	18.40	—	—	Do.
Do. average,	20.51	—	—	Do.
Malmsey,	16.40	—	—	Do.
Do.	12.86	—	—	Christison.
Teneriffe,	19.79	—	—	Brande.

The analyses of **BRANDE** are calculated upon eighty-nine per cent. of alcohol and eleven of water; of **CHRISTISON** and **ZIZ** upon absolute alcohol.

FRENCH.		Alcohol in 100 parts.	Specific gravity.	Analyst.
Claret,	17.11	—	—	Brande.
Do.	16.82	—	—	Do.
Do.	14.08	—	—	Do.
Do.	12.90	—	—	Do.
Do. average,	15.10	—	—	Do.
Do. first growth, 1811,	7.72	—	—	Christison.
Do. Latour, 1825,	7.78	—	—	Do.
Do. Rose,	7.61	—	—	Do.
Do. ordinaire,	8.99	—	—	Do.
Champagne, still,	13.80	—	—	Brande.
Do. Mousseaux,	12.80	—	—	Do.
Do. red,	12.56	—	—	Do.
Do. pink,	11.30	—	—	Do.
Do. average,	12.61	—	—	Do.
Do.	12.10	—	—	J. Fontenelle.
Do. Burgundy,	16.60	—	—	Brande.
Do.	15.22	—	—	Do.
Do.	14.53	—	—	Do.
Do.	11.95	—	—	Do.
Do. average,	14.57	—	—	Do.
Do. 20 years in bottle,	12.16	—	—	Prout.
Hermitage, white,	17.43	—	—	Brande.
Do. red,	12.32	—	—	Do.
Côte Roti,	12.32	—	—	Do.
Roussillon,	19.06	—	—	Do.
Do.	17.26	—	—	Do.
Do. average,	18.13	—	—	Do.
Sauterne,	14.22	—	—	Do.
Nice,	14.63	—	—	Do.
Barsac,	13.86	—	—	Do.
Vin de Graves,	13.94	—	—	Brande.
Do.	12.50	—	—	Do.
Do. average,	12.08	—	—	Do.
Grenache,	21.24	1.053	—	Prout.
Frontignan,	12.79	—	—	Brande.
Rivosalet,	9.31	—	—	Christison.
Lunel,	15.52	—	—	Brande.
Do.	18.01	—	—	Fontenelle.

SICILIAN AND ITALIAN. *

Marsala,	26.03	—	—	Brande.
Do.	25.05	—	—	Do.
Do. average,	25.09	—	—	Do.
Do. 21 years old,	18.20	—	—	Prout.
Lissa,	26.47	—	—	Brande.
Do.	26.35	—	—	Do.
Do. average,	25.41	—	—	Do.
Do.	15.90	0.9913	—	Prout.
Lacryma,	19.70	—	—	Brande.
Syracuse,	15.28	—	—	Do.
Do.	30.00	0.9911	—	Prout.
Etna, red,	18.90	—	—	Faraday.
Do. white,	18.16	—	—	Do.
Do. Sinical,	19.00	—	—	Do.
Do. white Falernian,	18.19	—	—	Do.
Do. red,	20.00	—	—	Do.
Aleatico,	16.20	1.020	—	Prout.

GERMAN.		Alcohol in 100 parts.	Specific gravity.	Analyst.
Hochelmer,	14.37	—	—	Brande.
Do.	13.0	—	—	Do.
Do. old in cask,	8.88	—	—	Do.
Do. average,	12.03	—	—	Do.
Joannisberger, 1788, 9.38 parts acid in 100 by weight,	8.71	0.9978	—	Prout.
Rüdesheimer, 1811, 6.22 parts acid in 100 by weight,	10.72	—	—	Do.
Do. 1800,	12.22	0.9960	—	Ziz.
Do. superior,	8.40	—	—	Christison.
Do. inferior,	6.90	—	—	Do.
Hambacher,	7.35	—	—	Do.
Oestricher, 1801,	8.46	0.9960	—	Ziz.
Do. 1802,	10.50	0.9890	—	Do.
Do. 1804,	10.66	0.9920	—	Do.
Zornheimer, 1802,	10.11	0.9790	—	Do.
Do. 1803,	9.00	0.9960	—	Do.
Do. 1804,	8.75	1.0310	—	Do.
Rodenheimer, 1802,	13.96	0.9890	—	Do.
Rhenish, four years, un- der Soemmering's pro- cess, 10.58 parts acid by weight,	7.58	0.9997	—	Prout.
Do. natural state, 10.58 parts acid in 100,	7.36	0.9992	—	Do.
Do. three years under Soemmering's process, 8.4 parts acid in 100 by weight,	7.00	0.9968	—	Do.
Steinberger,	10.90	1.0025	—	Geiger.
Marcobrunner,	11.60	0.9985	—	Do.
Leibfrauenmilch,	10.60	0.9939	—	Do.
Geisenheimer,	12.60	0.9945	—	Do.

HUNGARIAN.

Tokay,	9.33	1.054	—	Brande.
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PERSIAN.

Shiraz,	15.52	—	—	Do.
Do.	12.95	—	—	Christison.
Do.	19.80	0.9914	—	Prout.

CAPE OF GOOD HOPE.

Cape Madaira,	22.94	—	—	Brande.
Do.	20.50	—	—	Do.
Do.	18.11	—	—	Do.
Do. average,	29.51	—	—	Do.
Cape Muscat,	18.25	—	—	Do.
Constantia, white,	19.75	—	—	Do.
Do. red,	18.92	—	—	Do.
Do. do.	14.50	1.081	—	Prout.

REDDING has given an analysis in another form, as follows; but has not stated his authority:—

	Absolute Alcohol.	
	Ounces.	Drachms.
Port, in bottle of 26 oz., seven years in glass,	2	7
Do. 25½ oz. one year in bottle, two in wood,	2	4
Pale sherry, 25 oz., three years old,	2	6
Another specimen,	2	7
Madeira, 25½ oz., two years old,	2	5
Cape, 25 oz., one year old,	2	8
Old hock, 21 oz.,	1	0
Brandy, 24 oz.,	10	0
Rum, 24½ oz.,	9	8

MULDER, who has had great experience in the analyses of wines and spirits, states that alcohol varied as follows:—

	Per cent.		to	Per cent. by measure.
	20.70	23.20		
Port,	15.40	24.70		
Sherry,	19.00	19.70		
Madeira,	19.90	21.40		
Claret,	9.10	11.10		
Burgundy,	10.30	13.20		
Rhine wine,	9.50	18.00		
Moselle,	8.70	9.40		
Champagne,	14.10	14.80		
Brandy,	52.40	53.80		

Eighteen per cent. alcohol by weight are equal to about twenty per cent. by volume.

The wines of Palestine, Syria, and Asia Minor vary much in alcoholic strength. Those analyzed by Professor HITCHCOCK of Amherst College, United States of America, contained from ten to eighteen per cent. of alcohol, or nearly as much as the European wines, except those of Oporto, Madeira, and Sicily, or the low wines of Spain that are brandied.

Of late years Australia has become rather prominent as a wine-producing country. The Editor's brother, Mr. FREDERIC MUSPRATT, who has resided there for some years, writes as follows:—

Wine has been made in Australia during the last thirty years, but has not been known in the towns till within the last ten years, owing to the great demand for it in the country. The vine flourishes more or less in all those latitudes, but the climate of New South Wales must be admitted to be the best adapted for wine-growing, and vineyards are established on the banks of the Hawkesbury, the Nepean, the Hunter, the Williams, and the Paterson, which are capable of being greatly augmented, to meet any demand there may be made for wine; and a rapidly increasing population will doubtless hasten their extension. The quantity of wine produced in 1857 was about three hundred thousand gallons.

The wines best known in Sydney and Melbourne are Irrawang, Tomago, Caewarra, Camden Park, Kinross, Kaludah, Porphyry, Tanilba, Wivenhoe, *et cetera*, and the *crû*—characteristic flavor—of the different varieties is as marked as is that of *Chateau Lafite*, *Margaux*, or other European wines.

A Burgundy wine is best at Irrawang; a champagne at Kaludah and Caewarra; a medoc at Tomago, Kinross, and Tanilba; a hermitage at Porphyry; a muscat at Camden Park; and a Graves at Tanilba.

The vineyards are principally worked by Germans, and the cellar-masters have learned their craft at Frankfort-on-the-Maine in Europe; so the local prejudice against colonial wine, manufactured formerly under the superintendence of squatters, who never had any experience in wine-making, is rapidly disappearing, the grape being richer in sugar than that grown on the Rhine-board. The ordinary wine of the country is considered generally to be superior to that of Germany. There has not been time to test, on a large scale, the capability of producing extremely fine wines, but, judging from the fact, that wine thirty years old is as rich in flavor and bouquet as wine the same age in Europe, there can be but little question as to the quality. At the Paris Exhibition of 1855, the jury, upon tasting a red wine, two years old, called it a *joli vin, beaucoup d'avenir*, and awarded it one of its highest numbers. All present expressed their surprise at the result of the examination, and highly approved of the wines. The foreman said they were perfectly astonished at the quality of the Australian wines, and were unanimous in giving them the place, for strength and flavor, between the wines of Madeira and those of the *Côte du Rhone*.

A Sydney trade circular, describing the wines at present in the market, says:—The wines of this colony are essentially Australian in general character. They

assimilate to the French and German wines. Some are considered by connoisseurs to resemble hock, Sauterne, claret, Burgundy, and the like, but no attempt is made to imitate these or any other wines. Of course, the vines are in great variety, but, from whatever description of grapes they are made, each vineyard has a peculiar local character, distinguishable by vinists. The Camden wines will first be noticed. These are of three sorts, namely—white, which resembles the Rhenish wine; red, which approaches Burgundy in taste; and muscat, rather like the Frontignac of the Cape, malmsey, or Madeira. Now for the Irrawang wines. The white is considered like hock or Sauterne; of the red there is at present no stock; and the sparkling Muratta is a very fair champagne. Next, the Wivenhoe wines will be referred to. These are—the white Muscat, resembling hock; red, corresponding in flavor with Rhenish wines; Madeira, which is of a Frontignac description; and Reissling. There are some wines grown at Oatlands, near Paramatta—the red resembles a claret, and the white corresponds with a light French wine. Under the head of Notes and Queries in the *Spectator*, is the following:—The samples of Australian wine at the Paris Exhibition have earned special commendation. When the horticulturists of that colony shall have succeeded in extending the cultivation of the vine over the land of the dreary Eucalyptus, one may imagine that it is destined to the nurture of a British BACCHUS, and may look forward to the importation of Australian wines; and upon its arid soil, even upon the chasm of pools that its rivers present in the summer, would be exhibited the same miracle which is to be seen in the South of Europe, the juicy grape growing upon a parched soil, and for a season would be clothed with the loveliest foliage under the sun. Fancy the change of character that must come over the British stock habitually living in such scenes, under such a sun, with such a diet. It will be an experiment somewhat such as the world might have witnessed had the Saxon been planted in Italy. These queries are curious, as indicating the notions of the untravelled; but parties are daily getting more accurate knowledge as to the actual capabilities of the British Colonies.

The vineyards in the neighborhood of Adelaide, South Australia, are rapidly extending, and on the banks of the Murray and Murrumbidgee; the wines that are grown there will bear comparison with those of other lands. The only drawback to a rapid increase in the wines made in Australia lies in the dearth of labor; but as all the farmers along the thousands of miles of river banks are all planting their small vineyards—which may be tended by their wives and children—and as merchants, who will buy the juice and await its ripening, are establishing themselves at convenient places, there is every prospect of the trade becoming greatly enlarged.

In the ripening of wines Australia possesses an advantage over Europe. As there is no winter there, so is there no check to the fermentation after the juice has been removed from the vats to the casks. This check to the fermentation in Europe is the cause of much wine fouling, and is the mother of many of the

so-called *sicknesses in wines*. This is a source of great anxiety to many of the large European *vignerons*. On account of the hot winds in Australia, the vines are pruned low; and as this method, combined with a hot sun, causes more *must* to be in the grape than is usual in Europe, it is found that the fermenting juice will, as a rule, bear a large quantity of *stalk*; the consequence is, that the elements of bouquet are much more prominent than with wines of the same strength in Europe.

The foregoing remarks are well worthy of attention. Good and sound wines doubtless have been made in Australia; but the Editor is not so certain whether the English will ever admit any wine produced in the colonies to be equal in that beautiful aroma—which science has not yet been able positively to assert what it is—and flavor belonging to the first-class wines of Europe—Johannisberg, Sauterne, Rudesheimer, Liebfraumilch, *et cetera*.

In 1852, specimens furnished to Baron LIEBIG will explain the result of an attempt at wine-making in that colony. This wine, principally from the grape called the *pineau noir* and *gris*, carried a specific gravity of 0.992, and gave 16.20 per cent. of alcohol; 0.505 of free acid; 3.265 of dry residue; and 0.498 of incombustible ashy constituents. Another species of white wine grown at Irrawang had a specific gravity of 0.94; gave out thirteen per cent. of alcohol; 0.66 of free acid; 3.313 of dry residue, chiefly saccharine; and 0.563 per cent. of ashy constituents—proportions met with in some of the European wines, particularly the German. LIEBIG also analyzed other wines of Australia, and among them one obtained from the white muscat grape, which gave 19.53 per cent. of alcohol and 0.64 of free acid.

The wines of South America have not been analyzed. They are scarcely known in Europe. There is, however, a red wine made at Chili which is much liked by Frenchmen, and is considered a very fine *vin ordinaire*; instances being known of French men-of-war putting in to Chili and stocking their vessels with hogsheads of it.

The difference in the intoxicating effect of wine, and brandy and water, it has been asserted does not exist. Professor BECK, taking brandy at 53.39 of alcohol, calculated strong Madeira at 48.26; weaker Madeira, 36.14; port, average, 42.33; Bucellas, 35.21; sherry, 33.75; Sauterne, 24.34; claret, 21.38. He is of opinion that the difference between wine and brandy and water is more fanciful than real. New wine is more intoxicating than old, although the latter is more spirituous; and, according to SOEMMERING, loses of its aqueous parts by age. BRANDE, with good reason, supposes that when brandy and water are allowed a sufficient time for combination, the intoxicating power may not be more than that of wine containing an equivalent of brandy. Thus the effect of brandy and water arises from their imperfect union. On the other hand, it is certain, that the evil effects of the two, when taken in excess, upon the animal system are very different. Fine pale cognac—HENNESSY or RENAULT'S—with water, is often prescribed for invalids, and with great success. The Editor is of opinion that such a beverage taken constantly is less injurious than heavy, and especially drugged wines.

In some places in the North of Europe wine has been exposed to severe frost, under the idea of imparting strength to it, by drawing off the unfrozen portion. In the Augustan age, when the Euxine sea used to be frozen over, the wine in the casks, it is said, was cut with hatchets. Mr. PARKES experimented on wine exposed to 22° below the freezing point. He could discover no difference in taste between the fluid frozen and unfrozen, and thought the unfrozen the more vivid of the two. Of five hundred and sixty grains of port wine, five hundred and forty remained liquid; and of sherry two hundred and eighty-five grains were frozen, and one thousand and fifty-six remained in a fluid state—a result not in accordance with the experience of the colder wine countries of Europe.

The various matters discoverable in wine are not all found in the same growths. Less or more in some, and none at all in other kinds, with ever varying quantities, render analysis only good in relation to single specimens, and of no service in laying down a general rule for all. Thus water, sugar, alcohol, gum, extractive and nitrogenous matter, or albumen; the bitartrate of potassa, sulphate of potassa, chlorides of potassium and sodium, and in red wine coloring matter, and tannin from the stalks; carbonic acid in sparkling wine, and a perfume or bouquet, a species of ether—*enanthic*, *acetic*, *et cetera*—found in the fermentation, and citric acid—a mere trace of the latter—have been found in wine. Malic and gallic acid were thought at one time, with tartar and sugar, adding the gluten, to be almost the entire of the principles discoverable, and that all wines were the same in this respect; but science has undeceived the world upon this point. The amount of sugar in some sweet wines is full thirty per cent. according to PROUST. White wines are more perfect than red, and will endure longer; perhaps arising from the absence of the acid taken up by gypsum in the making, which cannot be used in red wines. The color of the red wines sometimes approaches to black from intensity. Indeed, a powerful wine in France carries the name of the Black wine of Cahors, generally used for strengthening weak-bodied or light-colored wines. Port wine of the vintage 1812, and that of 1820—CHILLINGWORTH—are nearly black, although upwards of forty years old. From pink to black in red exist, and from water to a deep golden hue in white wines, and even a green color in the wines of Cotnar. Amber and brown in different shades are to be met with, but no merit in regard to the quality of the wine attaches to the hue, however agreeable one more than another may be to the vision. Perhaps the clarets—so named from the French *clair*et, which, however, attaches to a different species—hold the middle place in regard to color, between the light red and black. The coloring matter in red wines may be obtained by an exposure of the bottle to the sun's rays, when it will fall in flakes; the taste of the wine remains unaltered. Before adding lime water the coloring matter is precipitated with the insoluble salt formed by the wine and acid of the wine in union. The finer wines are generally those in which the color is most attended to by the maker, and the rivalry in this respect is considerable. It is a matter in which preju-

dico operates. Many people cannot be persuaded that a pure red wine, of a light color, may be far superior as a wine in every good quality to one deeply colored, even when perhaps, as in port wine, it is aided by the elderberry.

When red wines lose color on the Continent they are said to be *rancio*, rusty; in England tawny. The coloring matter deepens on the deposit of tartar, and the tawny hue arises from age. Heat, too, will injure the color, which is thus not necessary to the flavor of the wine, being no way dependent upon it. Carbonate of potassa, sometimes formed in wine, injures both the color and flavor. It arises from the decomposition of the tartar, and in France is called the *tornure*. A little tartaric acid being added, the potassa forms cream of tartar, depositing crystals.

Wines grow darker as they ameliorate up to a certain point, but this is not uniformly the case. The alcohol in the wine, diminishing by evaporation, has no relation to this change; indeed, it is probable, that the aqueous portion evaporates rather than the spirituous. The specific gravity of wine increases under those circumstances. Many affirm that the alcohol in bottled wine increases by age; MULDER asserts that such a statement is thoroughly false, the formation of alcohol in the bottles being impossible. SOEMMERING discovered, that there were substances which permitted the aqueous portion of wine to escape more freely than the alcoholic. Equal parts of alcohol and water were placed in a glass vessel, and the mouth closed with a piece of bladder.—See ALCOHOL. It was observed, that under the circumstances more water was lost than alcohol, but when the temperature was raised to 62° it passed through the bladder unchanged. From this, and other experiments, SOEMMERING took the idea of ameliorating wine by exposing it to a similar process. He, in consequence, covered a glass vessel full of wine with a bladder, and suffered it to remain eighty-one days aside in a warm dry room. During that time one-half had evaporated, and the residue had acquired a more spirituous, mellow, and agreeable flavor. The color was deepened, a film had formed over the wine, and a deposit of crystals had taken place at the bottom of the glass. The proportion of alcohol had doubled from 4.0 to 8.0. A repetition of the experiment gave the same result, and thus a more rapid mode of ameliorating wine was discovered, than keeping it in wood, to effect the disengagement of the alcohol and water by time. Hence the transportation of wines to a tropical climate and home again, exposing the wine to aqueous evaporation, easily accounted for the beneficial effect, and the same with heat artificially applied. Wines thus exposed, too, deposit rapidly. Thus it is a common trick with port wine-mixers to place the bottles in water, carry it to the boiling point, and then, taking them out and placing them in the cellar, *the crust so admired by the ignorant in port wine is immediately formed*. It has been advanced, in consequence of the foregoing discovery, that the amelioration of wines in the wood is effected mainly by the disengagement of some of their water—the alcohol being retained, or a smaller proportion of alcohol than water being evaporated, the rest of the wine becomes more

concentrated—and that for this purpose vessels are most desirable which will retain the alcoholic and permit the aqueous particles to escape. Wine is observed to evaporate more rapidly in chestnut casks than in those of oak or similar close-grained timber. To such an extent is this evaporation carried in chestnut casks, that the French have prohibited the exportation of brandy in any but what are made of oak. Hence it may be conjectured, that the larger the surface of the liquor exposed the more rapid will be the evaporation; and that as the fermentation is quickened by the larger bulk in action, so it is with vinous amelioration. There is probably a limit here, which it would be very desirable to ascertain, but to which discovery no approximation has yet taken place. The Germans of late years, as they have discovered that, beyond the point of maturity in wine, the long keeping once thought of so much importance is not really of any great moment, seem also to have discovered that tuns of a moderate capacity are fully as advantageous as the gigantic vessels, by their fathers deemed of so much moment, for mellowing their Rhine wines.

Wine is continually sophisticated and adulterated, especially such as is of a coarse nature, having no obvious standard of taste. Of such wines port is, from the common usage, and the different flavors imparted to the wines of that name, the most abused. It is clear that a wine of any given species, if pure, will differ very little more in flavor in any season than the strength or weakness of the must will occasion. The main characteristics of the wine will be present. In a first-class Burgundy wine, for example, it will always be possible to distinguish that the wine is the growth of the country assigned, and no other wines will be drank in its place that are not of the same order. This would be the case with all sound good growths, and with the wines of Oporto as well, had they not been continually deprived of their natural character by mingling, coloring, and brandy adulteration. A house—IRELAND and Company of Bristol—was renowned for its excellent Bristol port wine, and a handsome fortune realized. All at once, on the breaking out of the French revolutionary war, Bristol ports were no longer to be had, and IRELAND and Company wound up their affairs, because they could no more obtain the wines of the South of France, for which they were celebrated as port-wine merchants, not a cask of their wines having ever been in Portugal. Now, such a deception could not be practised with Burgundy, champagne, or the finer wines of France.

The Editor has repeatedly had *English-made port* sent to him, but the imitation in no instance deceived him. The *taste* was sufficient to detect the imposition.

The mingling of inferior wines with superior, or with brandy, is not the sophistication for which the chemical professor is so much required to confer a boon upon the public, as in detecting extraneous substances of no vinous character at all. To brandy intermixed with wine, and which never blends with it as the natural alcohol of the wine does, are owing, in many cases, the liver complaints of the wine drinkers in England—a disease rare in wine countries.

The alcohol in wine may be ascertained by adding

one part of a concentrated solution of subacetate of lead to eight of wine by measurement. A precipitate is thus formed: agitate the mixture for a few minutes; pour the whole upon a filter; and then collect the fluid. This fluid consists of the spirit and water, with a portion of the lead. Now add by little and little *pure*, warm, dry subcarbonate of potassa—not the salt of tartar, and subcarbonate of potassa of commerce—which has been freed by heat from water. This must be done until the last portion remains undissolved. The spirit in the fluid being thus separated by the potassa abstracting all the water, the former will be found a stratum upon the salt. The experiment should be made in a glass tube, from half an inch to two inches in diameter, graduated into a hundred parts; and thus the quantity of spirit may be read off at sight.

To detect elderberry coloring in port and other red wines, acetate of lead is the simplest test. With pure red wine it throws down a greenish-grey precipitate. A deep blue precipitate is the result of elderberries, logwood, and bilberries. Brazil wood and red sanders are thrown down red. Lime water destroys the color imparted by beet.

WATSON in his chemical essays, as to his assertion that lead has been used in wine, is contradicted by the best French chemists, who have never been able to find a trace of its usage, and assert that it cannot be of any service. In England, among the fabricators and amenders of base wines, sugar of lead and litharge have been ignorantly applied for cleansing white wines rapidly, according to their own statements. Ignorance and vice generally travel abreast. Thus to keep wines from turning, some one of the vulgar receipts has proved a very harmless one—Put in fair water a pound of lead which has been melted; then into the cask, pretty warm, and stop it close! Oyster-shell lime has been used for the same purpose, an ounce to two gallons of the wine. Cochineal, to the extent of half an ounce dissolved in wine or brandy, is one means used to improve color; and for port wine the compound called *geropiga* made in Portugal, and imported into England openly, as a *liqueur* solely for sophisticating port wine. Port and claret are rendered rough by baking two quarts of sloes in a gentle oven, or over a slow fire, until their moisture is given out. The fruit is squeezed, and a pint of the liquid is applied to thirty or forty gallons of the wine.

Substances native, such as genuine must, wine, alcohol, or sirup—that is, boiled wine—can alone be tolerated in mixing. All besides is more or less a fraud. The object of mixing litharge, potassa, and tartrate of potassa, is to arrest bad flavor and temper sharpness in new wine. Some substances for color, sugar and honey to sweeten, spices to improve the flavor, and perry and water to increase the volume, are complained of in France. There is a commission there of able chemists, who examine samples of wine with great care. First, as to litharge—a poison—no one instance of its use has ever been detected. In 1824 a petition was presented to the French chamber of deputies, making such a charge against the wine merchants generally, that the public were alarmed, and an inquiry was instituted. The result was, that no single instance

of the employment of litharge could be substantiated—that, chemically speaking, litharge was a substance which, from experiment, contributed more to the deterioration than the preservation of the wine, and the merchants had no interest in its use. The petition was rejected as without foundation. In analyses of the wine for fifty-five years, the French council of health never met with the traces of such a substance in wine. They only stated that they had to complain, that too much water and often perry had been mingled to increase the volume of the wine. Sirup of dried raisins had been used with colored water, and fermented and sold to imitate the wines consumed in cabarets, but never any deleterious substances, under countless analyses. M. JULLIEN experimented upon this substance in 1824. In a litre of musk in a state of acetous fermentation, one gramme and a half of powdered litharge was mingled and agitated several times for twenty-four hours, and then suffered to rest. The wine was tasted two days afterwards, and found as acid as at first, and unchanged in color. It was then filtered, and sulphuric acid being added, the white precipitate of the sulphate of lead was scarcely perceptible; but the sulphide of potassium, in another part of the liquid, caused a precipitate of the color of the lees of the wine. The result of four analyses was, that litharge did not deprive wine of its acidity, and contributed more to its decomposition than preservation; that in any considerable quantity it destroyed it, and that in a small quantity it remained in the wine in a state to be recognized with facility. If used in domestic wines, the same effect would follow. It was probable that the tartar of the wine had been mistaken for it. After all the scientific researches of foreigners into the nature of wine, they have not succeeded in detecting the quantity of perry, water, and not insalubrious ingredients, added by the dishonest dealer.

Fraude in blending wine, often too common, are not managed with substances foreign to the grape. The rinsings of brandy and ruin casks, Cape wines, cider, coloring matter, and tartar, or anything which will form a basis with Benecarlos, Figueras, red Cape, mountain, tartar, gum-dragon, cider, for port; and for coloring it red sanders infused for fourteen days in spirit of wine. Port is also made with that wine, twelve gallons; spirit of wine, six; brandy, three; rough fine cider, forty-two. A strong decoction of Brazil wood and alum imitate the favorite crust. Sherry is imitated, but the low-priced wine mingled with Cape answers the end. The notion that lead helps bad wine is current in England. But little faith is to be placed in such reports, since it has not the effect ascribed to it. Sulphide of hydrogen gas will detect lead in wine, turning it deep brown or black. Alum, sometimes used for astringency, or for the purpose of brightening the color, or of clarifying newly made wine, may be detected by first decoloring the wine—if red—by means of animal charcoal, previously washed with hydrochloric acid, filtering, and evaporating the liquid to about one-third of its volume in a porcelain or platinum capsule, and refiltering. If a precipitate has been formed while concentrating; if potassa, soda, or

chloride of ammonium produces when poured into the filtrate, a white precipitate soluble with the aid of heat in excess of alkali; if carbonate of potassa or soda produces a white deposit; if nitrate of baryta or or chloride of barium produces also a white precipitate insoluble in acid, *alum is present*; or as NORMANDY further adds, a given portion of the wine may be evaporated to dryness and ignited, the residue treated with a little hydrochloric acid, evaporated to dryness and re-treated with dilute hydrochloric acid. If now the addition of caustic potassa produces a white gelatinous precipitate soluble in excess of alkali, but which is reprecipitated by chloride of ammonium, then alum is present.

Not to follow these deceptions further—the field it may be inferred is a wide one for the investigation of science, by researches into the defects of wine itself, and pointing out proper remedies—the inequality in must of the product of the grape, from so many causes, requires to be obviated; but no rule can yet be laid down by which existing evils can be certainly avoided. Among the curious facts in relation to pure wines are the character of their deposits, so varied in form and density, according to the growth of the vine and temperature of the year when the vintage occurred. Some are oily, others muddy, adhering to the side of the bottle; and some are very light, so that on the least movement they mingle with the wine. Oftentimes the same wines will make a deposit in two different forms in the same bottle, one adhering to the sides or uniting in a mass at the bottom of the wine, the other suspended in the liquor. One species of deposit resembles litharge, and no doubt caused the report of its usage. In champagne wine the deposit is called *depot-pierre*, a precipitate in the form of very fine sand, or little scaly crystals, which are the tartar naturally deposited. All wine residuums contain more or less of this substance, but it is often so enveloped in the oily or muddy parts of the precipitate that it is not apparent. It is heavier than other deposits, and when mingled with the wine does not communicate any bad taste, alters its clearness very little, and when shaking the liquor ceases it falls to the bottom. This deposit is found in the better wines, and those having it preserve their excellence a long time, and are less subject to disarrangements than the wines the residue of which floats in the liquid. In order to investigate the nature of this substance, it is dried and placed upon burning charcoal. In consuming it emits an odor of burnt tartar, and on keeping up the fire, leaves a white residue which is found to be potassa.

The choicest wines keep the longest in bottle, and deposit there so much that, in order to have the wine perfectly limpid, it is necessary to decant them with great care. It is useless to place them in different bottles for no other reason but to secure transparency, as they will soon begin to deposit anew. Unless they are to be removed to a distance, or there is a fear of their acquiring a bad taste, they should remain untouched. This operation, when necessary, is to be performed with great care. Small glass or tinned siphons have been tried for delicate French wines, but not with the desired success. Crape or gauze has its inconveniences. An

instrument called a *cannelle-abrifer*, invented by M. JULLEN, is used for the purpose in France, as well as for chemical transfusions. For champagne more particularly it is well adapted. Wine is sometimes placed in demijohns, which hold from thirty to sixty bottles each, by which means it is well preserved; but the inconvenience of stirring up the deposit is in no way lessened on attempting to transfer their contents.

The disproportionate allowance of brandy thrown into wine is after all the great evil encountered in the wines destined for British consumption, and this is always to be detected by science. All wines of the highest class are deemed too weak and thin. The merchant imagines that it prevents acetous fermentation, and he knows that it blends all qualities into that which is most plentiful. Dr. McCULLOCH denied that it suspends acetification; Mr. CADET says, that if administered to the one-seventieth of the entire value it will do so. Alcohol is not separated by the action of heat, since it has been effected at 56°; but, however, this may be, wine to which brandy has been artificially added, affects the nervous system to a degree far greater than wine in the natural state, and chemistry has not yet been successful in discovering any theory which will account for it. The following tables show the importations of wine and the amount for home consumption for the years mentioned in the respective columns:—

TABLE OF WINE IMPORTATIONS.

Years.	Tons French.	Tons. Portuguese.
1675	7,495	20
1676	9,645	83
1677	6,749	176
1678	7,212	199

French war—wine prohibited.

Years.	Tons.	Tons.
1679	8	1,013
1680	1	1,003
1681 .....	.. ..	1,718
1682 .....	.. ..	13,860
1683 .....	.. ..	16,772
1684 .....	.. ..	11,611
1685 .....	.. ..	12,885

French again admitted.

Years.	Tons.	Tons.
1686	12,760	288
1687	15,518	327
1688	14,218	448
1689	11,109	579

Here the French imports again interrupted. From 1697 inclusive, the returns were more exact and given in gallons, *videlicet*, together, French, Spanish, Portuguese, and Rhenish.

Years.	Tons.	Hds.	Galls.	Years.	Tons.	Hds.	Galls.
1697	13,086	3	43	1707	12,962	0	16
1698	12,974	2	15	1708	14,380	0	50
1699	21,553	3	25	1709	13,338	1	48
1700	23,502	0	10	1710	15,869	0	56
1701	21,443	2	23	1711	15,481	2	14
1702	15,725	1	62	1712	12,677	1	27
1703	11,092	2	42	1713	15,937	1	8
1704	13,811	1	57	1714	18,747	1	57
1705	12,070	1	17	1715	21,751	0	9
1706	10,973	2	31	1716	18,834	3	7

Years.	Tuns.	Hhds.	Galls.	Years.	Tuns.	Hhds.	Galls.
1717	22,260	3	58	1771	16,874	2	12
1718	23,875	1	48	1772	15,597	2	42
1719	20,510	2	13	1773	16,431	3	20
1720	19,141	0	44	1774	17,992	1	20
1721	25,268	0	45	1775	17,738	0	13
1722	25,470	0	42	1776	16,734	0	38
1723	22,415	1	1	1777	18,217	2	60
1724	23,075	3	8	1778	16,343	0	51
1725	24,722	3	35	1779	12,760	2	10
1726	19,334	0	24	1780	20,514	2	39
1727	21,064	3	61	1781	13,311	3	20
1728	30,045	2	32	1782	9,791	0	39
1729	25,672	3	50	1783	13,624	1	51
1730	19,823	3	31	1784	14,499	0	56
1731	24,339	1	58	1785	16,287	0	58½
1732	21,384	0	11	1786	16,242	3	53
1733	21,420	1	57	1787	23,324	3	33
1734	21,264	1	47	1788	25,560	3	52
1735	24,416	1	28	1789	26,299	2	60
1736	20,763	0	10	1790	29,144	3	13
1737	26,605	1	38	1791	33,155	1	33
1738	22,171	2	1	1792	35,525	3	51
1739	18,594	3	28	1793	22,788	3	40
1740	15,196	3	60	1794	30,259	2	2
1741	17,178	1	3	1795	35,608	3	51
1742	16,715	3	58	1796	23,693	1	37
1743	17,655	0	34	1797	15,901	2	30
1744	10,276	2	60	1798	23,287	3	49
1745	16,034	1	34	1799	33,419	3	7
1746	12,205	1	11	1800	32,332	1	26
1747	14,560	2	32	1801	38,893	1	21
1748	15,135	1	16	1802	30,407	0	53
1749	21,555	0	35	1803	37,913	1	62
1750	15,456	2	11	1804	19,419	3	2
1751	14,788	0	2	1805	33,463	0	55
1752	13,708	2	52	1806	35,910	0	55
1753	18,857	0	20	1807	39,789	3	29
1754	14,982	3	50	1808	47,143	3	49
1755	16,544	2	22	1809	49,762	3	17
1756	12,264	2	18	1810	47,058	3	25
1757	14,050	2	30	1811	20,787	1	4
1758	15,806	1	54	1812	35,082	1	17½
1759	15,405	2	19	1813	...	...	...
1760	15,427	3	47	1814	31,465	2	36
1761	14,602	3	46	1815	30,874	0	20½
1762	16,097	0	1	1816	18,218	0	57½
1763	17,082	3	21	1817	27,073	0	1½
1764	17,390	1	42	1818	35,763	2	9½
1765	18,132	1	4	1819	23,407	0	33½
1766	18,472	0	14	1820	22,781	1	55½
1767	17,087	3	5	1821	24,125	0	2½
1768	18,580	0	58	1822	27,454	2	25
1769	18,371	2	30				
1770	16,724	0	40				

The Methuen treaty to favor Portugal at the expense of France was signed in 1703—the duty on French wine to be one-third more than on that of Portugal. A tun of wine is two pipes, four hogsheads, or two hundred and fifty gallons old measure, or two hundred and thirty-one cubic inches. From the year 1785 the returns include all sorts and quantities of wine, however small. In 1813 the records were destroyed by fire at the Custom House.

About this time the returns were made in imperial gallons, the old measures being abolished.

Years.	Imperial Gallons.	Years.	Imperial Gallons.	Years.	Imperial Gallons.
1823	6,676,355	1835	9,030,551	1847	7,938,067
1824	6,637,506	1836	9,406,083	1848	7,536,730
1825	10,892,033	1837	8,033,480	1849	7,970,067
1826	7,586,937	1838	8,518,484	1850	9,304,312
1827	7,950,961	1839	9,909,056	1851	9,008,428
1828	9,637,951	1840	9,311,247	1852	6,793,304
1829	7,618,196	1841	7,708,502	1853	11,029,567
1830	6,879,588	1842	7,216,113	1854	10,875,855
1831	7,116,870	1843	6,807,053	1855	8,946,766
1832	6,018,460	1844	8,584,586	1856	9,474,694
1833	7,443,841	1845	9,469,776	1857	10,336,845
1834	9,766,116	1846	7,711,809	1858	5,791,656

TABLE OF WINE CONSUMPTION.

Wine consumption and proportion to population. Down to the year 1787 the importation and consumption were nearly equal.

Years.	Imperial Gallons.	Years.	Imperial Gallons.	Years.	Imperial Gallons.
1787	4,521,941	1811	5,629,792	1835	6,420,342
1788	6,650,614	1812	5,024,530	1836	6,809,212
1789	5,959,098	1813	4,565,477	1837	6,391,531
1790	6,601,038	1814	5,330,774	1838	6,990,271
1791	7,573,790	1815	4,624,105	1839	7,000,486
1792	7,851,707	1816	4,057,038	1840	6,553,922
1793	6,610,701	1817	5,142,829	1841	6,184,960
1794	6,811,974	1818	5,635,216	1842	4,815,222
1795	8,238,438	1819	4,615,212	1843	6,068,987
1796	5,776,260	1820	4,586,495	1844	6,838,684
1797	3,589,261	1821	4,686,885	1845	6,736,131
1798	5,265,768	1822	4,606,909	1846	6,740,316
1799	6,138,164	1823	4,845,060	1847	6,053,847
1800	7,294,752	1824	5,030,091	1848	6,136,547
1801	6,876,710	1825	8,009,542	1849	6,251,862
1802	7,113,416	1826	6,058,443	1850	6,437,222
1803	8,226,464	1827	6,826,361	1851	6,280,653
1804	5,457,691	1828	7,162,376	1852	6,346,061
1805	4,622,701	1829	6,217,652	1853	6,813,830
1806	5,825,178	1830	6,434,445	1854	6,775,858
1807	6,271,310	1831	6,212,264	1855	6,873,601
1808	6,331,875	1832	6,965,542	1856	7,367,874
1809	5,894,177	1833	6,207,770	1857	7,042,042
1810	6,521,293	1834	6,480,544	1858	6,697,146

The wine consumption, with a population of about eight or nine millions in 1787, augmented to nearly twenty millions of souls in 1851, showed little increase, in consequence of the duties on several classes of wines reaching fully to 500 per cent. That the means of purchase increased with the population, is shown by the augmented value of property assessed in 1803 = £115,351,952, and in 1843 = £181,322,202.—*James on the Wine Duties*, 1855. If, with eight or nine millions of souls, we consumed seven millions of imperial gallons, with twenty millions of population we should have consumed double that quantity, in place of no increase having taken place—spirit having been substituted.

	Imperial Gallons	Population.
1787 to 1792	39,158,218	8,000,000
1793 to 1798	36,871,802	8,500,000
1799 to 1804	41,107,197	10,812,000
1805 to 1810	35,466,570	...
1811 to 1816	29,231,036	13,296,177
1817 to 1822	29,273,636	14,072,331
1823 to 1830 (8 years)	50,583,970	16,000,000
1831 to 1836	37,495,674	10,255,605
1837 to 1842	37,936,392	18,664,761
1843 to 1848	38,574,512	...
1849 to 1854	38,909,486	20,919,531

The consumption of wine was three and a half bottles per head from 1785 to 1794. It fell to three bottles from 1794 to 1814; and from 1814 to 1820 to two bottles. After that one and three-tenths bottle per head.

From 1786 to 1794 the Portuguese wine consumed in Great Britain, principally port, was 75·67 per cent., because there were only two-thirds of the duty paid upon the wines of Portugal that were paid on other wines. The duties were equalized in 1831, and from that time to 1854 the consumption of port diminished, until, in 1854, it was only 36·69 of the whole consumption. Spanish wines, only 16·67 in the first period, rose to 38·34 per cent.; French wines that were only 3·26 per cent., had risen in 1854 to 8·12.

Table of the proportions of different wines consumed in England, for which the Editor is indebted to Mr.

JAMES, author of the *Wine Duties considered Financially and Socially, et cetera, 1855*:—

TABLE OF PROPORTIONAL CONSUMPTION.

Years	Colonial. Per cent.	Spanish Per cent.	Portuguese Per cent.	French. Per cent.	Sicilian. Per cent.	Madeira. Per cent.
1849	3·87	39·16	42·36	5·03	7·11	1·14
1850	3·82	38·36	43·73	5·29	6·61	1·00
1851	3·74	40·33	40·02	7·12	6·28	1·10
1852	3·82	41·08	39·23	7·05	6·12	1·1
1853	3·92	39·58	38·87	7·79	7·55	1·02
1854	3·75	38·33	36·67	8·15	11·82	0·06
1855	3·95	40·42	35·16	7·99	10·82	0·05
1856	4·02	39·81	34·03	8·33	10·43	0·57
1857	6·05	39·43	32·72	8·83	10·62	0·05
1858	10·89	39·67	28·69	8·54	10·33	0·05

Proportion of White to Red Wines consumed.

Years.	White.	Red.
1854	52·065	47·935
1855	54·32	45·68
1856	51·31	45·69
1857	54·85	45·15
1858	59·21	40·79

Cape import at half duty.

Imperial Gallons.	Imperial Gallons.
861,605	261,564
492,087	352,330
787,753	456,214
654,118	726,814

Cape consumption.

DECREASE IN IMPORTATION, 1858, COMPARED WITH THE PREVIOUS YEAR.

Total	Pipes	Decrease Pipes.
French imports	1,742	504
Portuguese imports	14,240	3,332
Spanish imports	20,078	1,114
Sicilian imports	1,900	114
Madeira and Canary	192	52
From Holland	79	32
Other places	2,339	401
British Possessions	1,427	..
Total	41,997	5,549 2,950 { Colonial increase at half duty deducted. 2,599 Decrease. 58 { Decrease mixed in bond. Total.....2,657 Pipes decreased.

The Cape wines at half duty increased in ten years, from 3·87 to 10·89. Spanish were stationary, or with a small increase. Portuguese decreased from 42·36 to 28·69. Other wines, except Madeira, increased.

In the monetary provisions of the government for 1860, the duties were reduced upon all wines of all countries and of our own colonies from five shillings and sixpence and five per cent., to take place on January 1, 1861, on wines of the lowest alcoholic strength, or not above 18°. These to be admitted at one shilling per gallon. The wines above this alcoholic strength at two shillings, or wines approaching 40° of proof spirit. This reduction to commence at first by a fall of duty to three shillings per gallon, from the existing five shillings and sixpence $\frac{2}{20}$.

The grocers' home made wines, free of duty, aided to supersede foreign wines in consumption, and thus injured the exchange of goods with the foreigner;

these wines or compounds having been sold at little more than the duty only on foreign wines.

The average product of wine in France is nine hundred millions of gallons; and in Paris two hundred and sixteen bottles per head are annually consumed; in Hamburg twenty-nine per head. The following table is the most authentic extant, and there is reason to think much within the real limit of the produce of the wines of Europe:—

	Gallons.
France	900,000,000
Hungary and Austria	500,000,000
Spain	220,000,000
Italy	193,000,000
German States, Prussia, Luxemburg, &c.	45,000,000
Portugal—total product	10,500,000
Sicily	3,000,000
The Azores	575,000
The Canaries	1,875,000
Cape of Good Hope 14,000 leagues of 60 gallons	840,000
Cyprus, Commandery, Muscadines, &c.	30,000
Servia, Wallachia, &c.	170,000
Total	1,876,990,000

Greece produces four millions six hundred and forty thousand oke; Asia Minor, Syria, Palestine, Persia, and the East produce wine, as well as some parts of Southern Russia.

The following tables, from *Redding on Wines*, contain a selection out of a number of the fine growths, of the names and character of the wines produced in the principal countries in Europe. To extend the list would be useless. In France alone, there are six classes of red wine, seven of white, and five of *vins de liqueur*. There are four hundred and sixty-three red wines, two hundred and forty-three white, and nine *de liqueur*. The champagne wines alone reckon six degrees in quality:—

WINES OF THE FIRST CLASS.

FRANCE, SPAIN, HUNGARY, GERMANY, SICILY, NAPLES, AND CAPE OF GOOD HOPE.

Wines.	Country.	Place.	Character.
Romanée Conti.....	France	Côte d'Or	The first and most delicate red wines in the world, full of rich perfume, of exquisite bouquet and fine purple color; light, yet with body and spirit sufficient to render them pleasant and healthful in use.
Chambertin.....	"	"	
Richembourg.....	"	"	
Clos Vougeot.....	"	"	
Romanée St. Vivant.....	"	"	
La Tache.....	"	"	
St. Georges.....	"	"	
Corton.....	"	"	
First growths of Prémaux....	"	"	
Musigny.....	"	"	
Clos du Tart.....	"	"	Burgundies, closely resembling the above growths in aroma, and all their other qualities.
St. Jean.....	"	"	
Perrière.....	"	"	
Veroilles.....	"	"	
Morgeot.....	"	"	White, highly esteemed.
Mont Rachet.....	"	"	
Lafitte.....	"	Gironde	Fine color and perfume, light, less warm than Burgundy, with a taste of the violet, and a rich purple hue.
Latour.....	"	"	
Château Margaux.....	"	"	Wines of the Rhône, darker in color than the preceding. Red Hermitage the most noted of these, of good body, and a fine flavor of the raspberry.
Haut Brion.....	"	"	
Beaune.....	"	La Drôme	
Muret.....	"	"	
Bessas, Burges, Landes.....	"	"	White, still, dry; of an amber color; generally iced for drinking.
Méal and Gréheux.....	"	"	
Racoule, Guionière.....	"	"	Fine effervescing wine, bright in color, slightly frothing.
Sillery.....	"	Marne	
Ay.....	"	"	The best of the white wines of Champagne, being all of the first quality, but differing a little in color and effervescence.
Mareuil.....	"	"	
Hautvilliers.....	"	"	
Pierry.....	"	"	
Dizy.....	"	"	Fine white wines of excellent quality, lightish brown in color, aroma most agreeable, and some of rather sweet taste.
Epemay—Closet.....	"	"	
St. Bris.....	"	Gironde	
Carbonneux.....	"	"	
Pontac.....	"	"	Description resembles the preceding.
Sauterne.....	"	"	
Barsac.....	"	"	Full of body, spirit, and perfume. The white is the finest of all white wines.
Preignac and Beaumes.....	"	"	
Château Grillet.....	"	La Loire	A rich muscadine.
Hermitage.....	"	Rhône	
Rivesaltes.....	"	Pyrénées Orientales	Straw wines, rich and luscious.
Colmar, Ollwiller, Kaiserberg.....	"	Haut Rhin	
Kientzheim, Ammerschwiir.....	"	"	Ditto.
Hermitage de l'aille.....	"	Rhône	
Amontillado Sherry.....	Spain	Andalusia	A dry delicate wine.
Schloss Johannisberger.....	Germany	The Rhine	
Lacryma Christi.....	Naples	Naples	A fine, luscious, sweet red wine.
Syracuse.....	Sicily	Syracuse	
Tokay Essence, and its first growths, called Tarczal, Szeghi, Zadany, Tolesva, also Erdo-Benye, Zambor, Tallya, Mada.....	Hungary	County of Zemplin	Thick rich wines, known as Tokay, also Tokay-ausbruch.
Cotnar.....	Moldavia	Cotnar	Very spirituous, by some preferred to Tokay. Greenish color.
The Commandery.....	Cyprus	Com. D.	
Constantia.....	Africa	Cape of Good Hope	
Lagrimas.....	Spain	Malaga	

SECOND CLASS.—FRENCH.

Wines.	Place.	Character.
Verzy, Verzenay, Mailly, St. Basle, Bouzy, St. Thierry.....	Marne	Red wines of Champagne.
Vosne, Nuits, Chambolle, Volnay, Pomard, Beaune, Morey, Savigny, Meursault.....	Côte d'Or	Excellent red Burgundies, very little inferior to first growths.
Ollivotes, Pitoy, Perrière, Préaux .. Chainette, Migrenne.....	Yonne	Good wines.

SECOND CLASS.—FRENCH.—(Continued.)

Wines.	Place.	Character.
Moulin à Vent, Torins, Chénas....	{ Saône et Loire, Rhône	Red.
Hermitage, second growths.....	Rhône	Red.
Côte Rôtie.....	"	Red.
Rozan, Gorze, Léoville, Larose, Branne-Mouton, Pichon-Longueville, Calon.....	Gironde	Red.
Côteau Brûlé.....	Vaucluse	Red.
Jurançon, Gan.....	Basses Pyrénées	Red.
Roussillon, Bagnols, Cosperon, Collioure, Torémila, Terrats, Masden.....	Pyrénées Orientales	Red.
Cranants, Avize, Oger, Menil.....	Marne	White Champagne wines, of good quality.
La Porrière, Comblotte, Goutte d'Or, Genevrière, Charmes et Meursault, Guebwillers, Turkeim, Wolxheim, Molsheim, and Rangen, in Belfort, Arbois, Pupillin, Châteauneuf Châlons.....	Côte d'Or	White Burgundies, of high repute in France.
Coudrieu.....	Haut Rhin	Dry, white, and <i>vins de paille</i> , of good repute.
Langon, Cerons, Podensac.....	Bas Rhin	Good wine, <i>mousseux</i> and still.
Montbazillac, Tcaulet, Raulis, Suma, Saneé.....	Jura	{ A white wine, which keeps long, of fine <i>sève</i> and perfume.
Buzet, Amazon, Viane.....	Rhône	White wines, capable of endurance.
St. Peray, St. Jean.....	Gironde	Good white wines of the country.
Jurançon.....	Dordogne	Generous white wines, of good body.
Frontignan and Lunel, Mazet.....	Lot et Garonne	{ Delicate <i>mousseux</i> and <i>non mousseux</i> , of agreeable flavor.
Bagnols, Collioure, Rodez.....	Ardèche	White, with an agreeable perfume of the truffle.
Maccabeo of Salces.....	Basses Pyrénées	Sweet, rich, and luscious; white.
	Herault	Red, styled <i>de Grenache</i> , rich and sweet.
	Pyrénées Orientales	Sweet, <i>vins de liqueur</i> .

THIRD CLASS.—FRENCH.

Wines.	Place.	Character.
Hautvilliers, Mareuil, Dizy, Pierry, Epernay, Taisy, Ludes, Chigny, Villiers-Alleraud, Cumières....	Marne	{ Red Champagne wines of the second quality; light and agreeable.
Ricey, Avirey, Baguoux la Fosse....	Aube	Resembling the preceding.
Gevrey, Chassagne, Aloxe, Savigny sous Beaune, Blagny, Santenay, Chénôve....	Côte d'Or	Good Burgundies of the third quality.
Clarion, Bonvin.....	Yonne	Ditto.
Fleury, Romanèche.....	Saône et Loire	Ditto.
Chapelle Guinchay.....	Puy de Dôme	Not wines of note; red.
Chantergues, Montjustet.....	Drome	{ Resembling red Hermitage; a little less full and fine, might be called Hermitage of the third quality.
Crozes, Mercurol, Gervant.....	Isère	Red wines, very middling of the class.
Scyssuel, Revantin.....	Rhône	Resembling Côte Rôtie.
Verinay.....	Gironde.	{ Pouillac, St. Estephe, good light red wines; Castelneau mediocre; the other growths agreeable.
Pouillac, Margaux, Pessac, St. Estephe, St. Julien, Castelneau de Médoc, Cantenac, Talence, Merignac, Canon.....	Dordogne	Resembling St. Emilion; keeping well.
Farcies, Terrasse, Campreal.....	Landes	Red; light colored, with a harsh taste.
Cape Breton, Soustons.....	Gard	{ Red wines, grown on the banks of the Rhone; will not keep good more than six years.
Chuzelan, Tavel, St. Genies, Virac, Ledenon, St. Laurent des Arbres, Chateaucuf.....	Vaucluse	Good red wines; keep well.
Riceys.....	Aube	Champagne; light and agreeable, white.
Rongeat de Meursault.....	Côte d'Or	Tolerable wine; not exported.
Vauvorrillon, Grises, Valmore, Grenouille, Vaudesir, Bourgeron, Mont de Milieu et Chablis..	Yonne	{ In considerable esteem in Paris as wines of the table. They are all white.
Pouilly and Fuissé.....	Saône et Loire	Much the same as the preceding.
Etoile, Quintignol.....	Jura	White.
Pujols, Hats, Landiras, Virelade, St. Croix du Mont, Loupiac....	Gironde	White; of middling quality.
St. Michel sous Condrieu.....	Loire	White; consumed in the country.
Frontignan and Lunel.....	Herault	{ Second growths of those famous and rich white wines.
Vins de Picardie of Marseillan and Pommersols. Vins de Calais, de Malaga.....	"	Rich luscious sweet wines, prepared in the department of Herault, and very little exported; also muscadines.
Moquevaire, Cassis, Ciotat. Vins d'Alsace.....	Bouches du Rhone	Rich sweet wines, boiled wines, and malmseys, of good quality.

SECOND AND THIRD CLASSES.—GERMAN.

RHINE AND MOSELLE.

Wines.	Place.	Character.
Johannisberger	Johannisberg	{ Grown near the Schloss Johannisberger, in the list of first growths already given. A very fine growth.
Steinberger	Rheingau	
Rüdesheimer { Berg	{ Rheingau, six leagues from Mayence, facing Bingen; on the hill and slope behind the houses.	Lighter than Johannisberger; fine bouquet. A highly prized wine.
Hinterhauser		
Laubenheimer	Mayence district	Lighter than Johannisberger, but delicate.
Kösterich	"	Ditto.
Niersteiner	"	A good wine, with fine flavor and body.
Oestricher	Worms	Ditto.
Liebfrauenmilch	The Rhine	Hence the word hoch. The first growth is the prime hoch wine of the importer. Light, agreeable—12-08, average of spirit. Some kinds, when new, contain as much as 14-37, according to BRAND.
Zornheimer	"	Choice wine, of fine flavor.
Wohlheimer	{ Spire, on the } { River Mayn }	Light, agreeable, good bouquet.
Graefenberger	Rheingau	An excellent wine.
Gaubischeimer	{ Near Mayence, } { the palatinate }	Ditto.
Deidesheimer	"	An excellent wine, light and delicate.
Oppenheimer	"	Ditto.
Bodenheimer	"	Of first quality.
Nackenheim	"	Ditto.
Braunberger	{ Moselle, Treves } { district }	Ditto.
Scharzberger	"	Ditto.
Granch	"	Ditto.
Zettingen	"	Ditto.
Wehlen	"	Ditto.
Piesport	"	Ditto.
Montagne Vert	"	Second quality.
Causel and Valdrach	"	Moselle, noted for diuretic qualities.
Rinsport	{ Moselle, Witlich } { canton }	Secondary Moselle.
Bacharach	Near Mayence	Wine once in high repute.
Becherbach	Becherbach canton	Secondary Moselle.
Walporzheimer	Upon the Ahr	Called wine of the Ahr.
Rutz	On the Moselle	Considered one of the Moselle wines.
Steeg	Near Bacharach	A light Rhine wine.
Montzingen	"	Inferior light Rhine wine.
Bodendorf	Near Bonn	A secondary wine.
Affenburg Hamen	Near Coblenz	Ditto, a Rhine wine.
Strang	Near Neider Breisig	Ditto.
Elzenburger	"	Ditto.
Alzenburger	"	Ditto.
Lutz	Near Treiss	Ditto.
Maas and Luhn	Niedar Heimbach	Ditto.
Stugerboeg	Rhine	Ditto.
Engchohe	On the Nahe	Called wine of the Nahe; secondary wines.
Niederborg	"	Ditto.
Leinenborn	"	Ditto.
Bangert	"	Ditto.
Rosenbech	"	Ditto.
Rensberger	Tarbach	Secondary Moselle.
Wurzgarten	Tarben	Ditto.
Anfuhr	{ Burg, left bank } { of the Rhine }	Ditto.
Rothenberger	Geisenheim	Soft, delicate, prime wine.
Scharlach	Mt. Scharlachberg	Fine flavored; rich aroma.
Roth	{ Near Hochheim, } { Spire district }	Hoch of good quality.
Königsbach	"	Ditto.
Weinheim	"	Ditto.
Forst	"	Ditto.
Ungstein	"	Ditto.
Schierstein and Narden	Wiesbaden	Tolerable wines.
Epstein	Near Frankfurt	Middling wines.
Phillipsch	"	Ditto.
Reichenberger and Wildenstein	Erbach	Inferior Rhine wine in quality.
Fenorbach and Laufen	{ Near Fribourg, } { at Badenweiler }	These are considered the best wines of Baden.
Heidelberger and Kleingenberger	Baden	Good wines of the country.
Bichenau Island	Lake of Constance	Ditto.

SECOND AND THIRD CLASSES.—GERMAN.—(Continued.)
RHINE AND MOSELLE.

Wines.	Place.	Character.
Meresberg and Überlingen.....	Near the Lake	Good wines of the country.
Cretzingen.....	Baden	Ditto.
Berghausen and Stellingen.....	"	Ditto.
Beringfield and Zeil.....	Bavaria	} Inferior wine.
Lindau and Ravensburg.....	"	
Schweinfurt.....	"	} Excellent wine, Rhenish character.
Liest.....	Württemberg	
Stein.....	"	Ditto, of a very dear price.
La Harpe.....	"	Inferior, but often sold for Stein.
Escherndorf and Schalsberg.....	"	Inferior to Stein.
Bischofsheim.....	{ Near Hanau, } Frankfort	} A tolerable wine, resembling Rhenish.
	Trieffenstein,	
Calmus.....	near	} A <i>vin de liqueur</i> .
	Aschaffenburg }	
Gnben.....	Saxony	Very poor wines.
Meissen.....	Franconia	A <i>vin de paille</i> ; aromatic.
Franconia.....	Rheingau, near	} Equal to the second class of Burgundy; excellent body.
Assmannshäuser.....	Rüdesheim	
Bessingheimer.....	Lauffen,	} Well tasted, good bouquet; called wine of the Neckar.
	Wurtemberg }	
Altenahr.....	Rhine country, left bank }	Inferior wines.
Mayschof.....	"	Ditto.
Rech.....	"	Ditto.
Ahrweiler.....	"	Ditto.
Bruch.....	"	Ditto.
Creutzberger.....	"	Ditto.
Hoënningen.....	"	Ditto.
Kesseling.....	"	Ditto.
Dernan.....	"	Ditto.
Blischert.....	Lintz	A tolerably good wine.
Neuwied Blischert.....	Hesse Darmstadt	Ditto.
Wangen.....	Bavaria	Poor, though esteemed in the country.
Naumbourg.....	Saxony	} Like fourth class Burgundy; styled <i>vins agre lets</i> .
The wine of Blood, Sang des Suisses	Bale	} A good wine, called also the Hospital and Cemetery of St. James.
Erlach.....	Berna	
Valteline.....	{ Made in the } Valteline	Remarkable for durability.
Boudry and Cortailods.....	Neuchâtel	Equal to third class Burgundy.
Cully.....	{ Near Lausanne, } and Vevay	} Like Rhenish.
Désalés.....	Between	
La Cole.....	{ Lausanne and } Coppet	Dry wines.
Bernang.....	St. Gall	} Tolerable of the country.
Frangy and Monnetier.....	Geneva	
La Marque.....	Martigny	} Red and white, and muscadine of tolerable quality.
Coquempin.....	Grisons	
Chiavenna.....		Aromatic, white, from red grapes.

SECOND AND THIRD CLASSES.

PORTUGUESE.

Wines.	Place.	Character.
Carcavellos, or Lisbon.....	{ Between Oeiras } and Carcavellos	Sweetish, white, well known in England.
Bucellas.....	Near Lisbon	} A fiery wine, from brandy being mixed with it; something like Barsac when pure.
Vinho de Termos.....	Estremadura	
Setuval.....	"	A light ordinary wine of the country.
Lamego.....	Near Coimbra	Two kinds, dry and muscadine; both good.
Alenquer, Monção.....	Estremadura	An inferior kind of Bordeaux.
Santorin.....	Near Lisbon	As the former, but somewhat better in quality.
Barra e Barra.....	Near Lavradio	An ordinary wine.
Colares.....	Near Cintra	A good wine.
Pazo da Regoa, Abasas, Villariño } des Freires, Gervães, Alvacoês, } do Corgo, Hornos, Guals, Con- } velinhas, Galafura, Lavradio... }	Mostly on the Douro	A light port, of good quality.
		Port wines of the Douro, of the first and second qualities, denominated Feitoria and Raimo.

SECOND AND THIRD CLASSES.

ITALIAN AND SICILIAN.

Wines.	Place.	Character.
Lacryma Christi	Naples, Mt. Vesuvius	Red rich muscadine, of a fine flavor and perfume.
Syracuse	Sicily	Luscious red muscadine.
Reggio	Naples	Resembling Burgundy.
Baia	"	Ordinary wine.
Mascoli	Sicily, Mt. Etna	{ The best red wines in the island, of excellent body, like the secondary Rhone growths; rare in the island.
Mascoli Sciarra		
Mascoli Macchia		
Mascoli San Giovanni		
Catania	"	Pitchy taste, ordinary <i>vinca</i> .
Tormina and Faro	"	Tolerably good.
Ovieto	Roman States	Excellent durable red wines.
Asti	Piedmont	Ditto.
Bianillo and Aleatico	Elba	Good wine of the second class.
Bischillato	"	A durable wine, exports well.
Procanico	"	A <i>mousseux</i> wine.
Chianti	Tuscany	A good wine.
Aleatico	"	{ Resembling the Tinto of Alicante in flavor and bouquet.
Carmignano, Antella, Artimino, Tizzana, Mentali, Lamporecchio, Monte Spertoli, Poncina, Glogoli, Val di Marini	"	Good wines of the country.
Naples muscadino	{ Mt. Vesuvius } Lake Averno Maria de Capona	Ditto.
Vino Greco	"	A delicate fine colored wine.
Carigliano	• Naples	An excellent muscadine.
Bari and Tarento	"	Muscadine, flavor of fennel.
Reggio	"	Muscadine and common.
Baia	"	<i>Vin de liqueur</i> .
Gierace	Near Reggio	Good ordinary wine.
Asprino	Campagna	Between light French wine and <i>vin cuit</i> .
Fundi	Kingdom of Naples	A <i>vin de mousseux</i> .
Val di Mazara { Mazara	Sicily	Of tolerable quality.
Veterano		
Corigliani		
Termini		
Girgenti	"	Ditto.
Messina, Milazzo, Avola, Vittoria ..	Lipari Isles	Ordinary wines, and superior muscadine.
Lipari and Stromboli	Near Bologna	<i>Vin cuit</i> and <i>mousseux</i> .
Imola	Near Spoleto	Good wines.
Terni	Near Castri	Good muscadine.
Farnese	Roman States	Muscadine, not durable.
Ovieto (white)	{ Near the Lago } Bolsena	{ A strong muscadine, finely perfumed and flavored; of great strength.
Monte Fiascone	Roman States	Ditto, excellent.
Albano	"	{ <i>Vins de liqueur</i> , of greater or less merit; not bearing exportation.
Moscato	"	Good wine, but a small quantity made.
Aleatico	"	
Vino Santo	Plain of Pisa	Weak wine.
Vernaccia	Tuscany	The most esteemed of the Tuscan muscadines.
Riccia	"	Good muscadines.
Buti	Elba	A cordial wine, prepared with wormwood, &c.
Monte Pulciano	"	Good muscadine.
Montalcino, Rimenezze, Pont-Ecole, and Santo Stephano	The Veronese	Deficient in spirit and strength.
Vermut	"	Good red and white wines.
Rio	Lake of Como	Wines of color and spirit.
Vino Morto	Mantua	An agreeable wine.
Bollagio	Pavia	Both dry and <i>mousseux</i> , but very inferior wines.
Labusca	Milan	Good flavored wines.
Pavia	Parma	Ordinary wines of the country.
Monte di Brianza	Placentia	Ditto.
Panocchia, Vigatto, Traversetolo, Casola, Avola, Azano		
Val Irdone, Bottola, Ponté d'Al-lolio, Verdetto, Sala del Christo, Creta	District of Borgo	{ Inferior wines, some of them <i>vins de liqueur</i> , having a disagreeable taste of honey.
Santo Pretasso, Frescale, Caselle, Lassarasco, Rugarolo, Castellina, Salso, Maggioré, Villa-Chiara, Claretto, Puzolo	Placentia	Ordinary wine, for home consumption.
Raterra and Sapolo	Modena	
Vin Piccolit	Friuli	Resembling Tokay.

SECOND AND THIRD CLASSES.

HUNGARIAN, AUSTRIAN, AND SCLAVONIAK.

Wines.	Place.	Character
Tokay, Essence, and Ausbruch	{ Near Mt. Tokay, Hungary }	See wines of first class.
Tokay, Maslas	"	A secondary Tokay.
Gyöngyösch	{ Mount Matra, Upper Hungary }	Wines, both red and white, much esteemed.
Edenbourg	Lower Hungary	Ditto.
Meneser	District of Arad	Red, much esteemed for spirit and sweetness.
Mencser-Ausbruch	"	{ Like Tokay, preferred by some; rich, aromatic, sweet, not cloying.
Erion	Upper Hungary	Good red and white wines, and an Ausbruch.
Rusth	Lower Hungary	Similar to Edenbourg.
St. György	Near Presburg	{ A white wine of excellent quality, somewhat in aroma like Tokay.
Ofen	Near Pesth	Good wine of the country.
Carlowitz	{ On the Danube, in Slavonia }	Resembles Cote Rotie.
Buda	{ Near the ancient capital }	Like Burgundy.
Sexard	{ Between Buda and Essek }	{ Resembles Languedoc, a good red wine of the country.
Gros Warden	{ Near Transylvania, the fortress }	Ditto.
Schiller	In Sirmian	Strong and sweet, of a red color.
Wermuth { Palunia	"	Wines prepared with spices and wormwood.
{ Tropfweruth	"	Scarcely different from Meneser.
Glodova, Menos, Gyordk, Paulis	Menes	Excellent wine, resembling Burgundy.
Modeon	Near Presburg	Ditto.
Katschdorf, Grunau, Obernusdorf	"	
Neustoad, Zschelhae, Kosrad	Near Buda	
Wersitz	In the Bannat	{ Wines like Burgundy and Bordeaux.
Jobhagy, Etsey, Sotvesch	Bannat of Tameswar	Good red wine.
Weisskirchen	"	Ditto.
Zips, Arva, Liplow	Croatia	White wine.
Buckwitz	"	Ditto; same quality.
Vinitza, Toeplitz	Transylvania	Wine of the country, Ausbruch.
Birihalm	Sebenico, Dalmatia	A wine highly characterized; not the <i>liqueur</i> .
Marachina	Moldavia	Green in color, and strong as brandy.
Cotnar	Wallachia	Light, rivalling Tokay.
Piatra	Ragusa	Good country wine.
Gravosa	Slavonia	Good red wine.
Semlin	"	{ Both red, and of agreeable flavor, and much spirit.
Syrmia and Posega	"	Red wines, which will not keep.
Podskalchi	{ Circle of Leutmeritz, Bohemia }	Ditto, like Burgundy.
Melnick	Circle of Bunzlow	Good wines, equal to Hungarian.
Poleschowitz	Moravia	Ordinary wine.
Mount Calenberg	Austria	
Hoefflein, Kloster Newbourg, Unter Katzendorf, Kaplenburg, Misdorf, Salsendorf, and Lichtenstein	"	{ Wines of little note, generally of a green hue, and drank young.
Giberwein	{ Southerly, near Vienna }	{ A wine that will keep, though of no extraordinary quality.
Spitz	"	Good wine.
Luttenberg	Lower Styria	Good wines, red and white.
Radskersbourg, Arnfels, Windisch, Gonowitz, Kerchenberg	"	Of the next rank to the foregoing.
Sansal, Leitschach, Pickerne, Stadlberg, Pulsgau, Sauritsch, Raen, Rast, Peitersberg, Wiesel	"	Good wines of the country.
Moettling, Weinitz	Carinthia	Resembling good Italian wines.
Freyenthurn, Wipach, Tscheremle, Marzamin	"	Ditto.
Proseco Antignana, St. Serf Tricste Berchotz	Istria	Red and white, sparkling and well flavored.
St. Patronio, Petit Tokai, St. Thomas, &c.	{ An Adriatic island At Capo d'Istria, Pirano, and Cittanova }	Red wine, deep colored and sweet.
Corregliano	Istria	Good <i>vins de liqueur</i> .
Izszgard	In the Tolna district	A good wine, consumed at Venice.

SECOND AND THIRD CLASSES.—SPANISH.

Wines.	Place.	Character.
Val de Pefias	New Castile	Good body, deeper than Bordeaux in color.
Manzanares	Manzanares	An inferior Val de Pefias.
Ciudad Real	New Castile	A tolerable red wine.
Albacete	"	Ditto.
Vino Tinto, Alicante	Valentia	Yellowish red color, when old called Fondellol.
Mataro	Catalonia	Good bodied and generous.
Torre, Beni Carlos, Santo Domingo, } Segorbe, Perales, Vineroz	Valentia	{ Wines of good body, some of the most esteemed red growths of the country; color deep.
Hospital	Aragon	{ Excellent flavor and body, from the Garnacho grape.
Carignena	"	{ A vino tinto from the same fruit.
Tinto Olivencia	Estremadura	{ Excellent red wine, the best in Spain.
Tinto di Rota, or Tiutilla	Andalusia	{ A sweet reddish cordial wine.
Ribidavia	Gallicia	{ An ordinary red wine.
Chacoli	Biscay	{ A very harsh austere wine.
Guindro	Malaga	{ Dark, flavored with cherries.
Tinto di Malaga	"	{ Seldom exported, a good wine.
Aleyor	{ Minorca, near } Mount Taurus }	{ A red wine, consumed on the island.
Palma	Majorca	{ A full-bodied wine.
Cordova	Andalusia	{ Good red wines of the country.
Mirando de Ebro	Old Castile	{ A luscious sweet wine.
Carbeson	Valladolid	{ A luscious sweet wine, with a burnt taste.
Terra del Campo	Old Castile	{ A luscious sweet wine, fine and delicate.
Velez Malaga	Malaga	{ Resembling sherry, dry.
Malaga	"	{ Pale and brown sherry.
Pedro Ximenes	"	{ A second growth sherry.
Malaga Xeres	Xeres de la Frontera	{ A yellowish-white wine.
Xeres vino seco, pale and brown ..	"	{ A sweet wine, of light amber color.
Abocado	"	{ Used to lower the sherries at Xeres, of which it is an inferior species.
Huesca	"	{ A sweet wine, of a yellow color.
Paxareto	{ Frontera and } St. Lucar }	{ A dry wine, of good bouquet and flavor.
Moguer	Niebla, Andalusia	{ A luscious wine.
Negro Rancio	Rota	{ A light red muscadine.
Montilla	Cordova	{ Dry white, of inferior quality; a <i>vin du pays</i> .
Borja	{ Arragon and } Tarragona }	{ Ditto.
San Lucar di Baramela	Andalusia	{ A well-flavored wine.
Manzanilla	"	{ A <i>vin de liqueur</i> .
Zalonge and Carlon	"	{ Malmseys of two qualities.
Yopes	New Castile	{ White dessert wines. Peralta is a Rancio when aged.
Fuenceral	"	{ A <i>vin de liqueur</i> .
Sitges and the Priory	Catalonia	{ A dry kind of Rhenish.
Peralta and Tudela	Navarre	{ A wine resembling Madeira, of inferior quality.
Pollentia	Majorca	{ A green wine, not now made.
Alba Flors	Minorca	{ A rich Malmsey, having a taste of the pine apple.
Vidonia	The Canaries	
Verdona	"	
Palma	"	

MADEIRA AND THE AZORES.

Wines.	Place.	Character.
Malvasia, or Malmsey	Madeira	Rich and sweet.
Madeira	"	A durable, dry wine.
Sercial	"	Ditto, of excellent quality.
Muscatel	"	Not exported; a good wine.
Tinto	"	{ A red wine, changing in twenty years to rich old Madeira in color.
Figa do Pereiro	"	{ Of inferior kind to the above.
Santo Antonio	"	{ A species of Malmsey, of light quality; keeps ill.
Vino Passado	Pico, in the Azores	{ A dry wine, light, not durable.
Vino Seco	"	

DOMESTIC WINES.—The grape ripens too seldom in England to be applied with advantage to the making of wine. The warmth of September is not sufficient to mature the grape; though up to some time in August, and generally to the end of that month, the vine may progress favorably. There are many fruits, however,

from which very palatable household wines can be made, and from which dull wines are continually manufactured, when those more lively can be introduced from the produce of the orchards, gardens, and fields of England. The mode of making these wines is generally not well understood; if it were, the wines would be much more palatable. Yeast, resorted to for the purpose of fermentation, often imparts a nauseous after-taste to the wine, which would ferment well enough in the natural way. There is nothing unwholesome in these wines, if properly made; and to this end the wine of the grape, and its mode of management, should be clearly comprehended, that its principles may be made applicable to domestic wine manufacture. The malic acid in the wines of English fruit often causes a trifling inconvenience to the *prima vie*, which acid may easily be exterminated in making the wine. The wine of the grape should be the model after which all wine of the garden-growth should be fermented—general principles should be first mastered. Suppose the gooseberry be taken as the fruit, it contains centesimally:—

	Units.	Ripe.
Green coloring matter,.....	0.03	—
Sugar,	0.52	6.24
Gum,	1.36	0.78
Albumen,	1.07	0.87
Malic acid,	1.80	2.41
Citric acid,	0.12	0.30
Lime,	0.24	0.29
Lignin, with seeds,	8.15	8.01
Water,	86.41	81.10
	100.00	100.00

The above are all the requisites for making wine, and some that are to be dispensed with; a deficiency in tartar is often noticed, but this can be supplied artificially. The excess of malic acid, on the other hand, is injurious; but as in making white wines in the South of Spain, this acid is got rid of by sprinkling powdered gypsum over the grapes, which takes it up, the same means should be adopted when making domestic wines in England.

Sugar is the first constituent in wine-making, and as it does not abound in some garden-fruits in England, it must be added. Cane-sugar, it has been seen, differs from grape-sugar in its proportional parts, but it is converted into grape-sugar by the process of fermentation. It is a sugar which goes slower into fermentation than that of the grape, and the alcohol in the wine always bears a proportion to the pre-existent sugar. This sugar uniformly contains a portion of a vegetal extractive matter, unless it is separated from it by art. The natural sugar of some plants also contains, some more, others less, of this sweet vegetal matter. If there is much of it in the sugar, the wine will be dry and perfect, because all the sugar will have been changed into alcohol. The mucilage, or vegetal extractive matter, like the gluten of wheat or albumen, contains azote, the gas of which has been noticed in grape wine making. This matter, found too in yeast, thus acts in exciting fermentation. Most garden fruits possess it; and it is this sweet principle combined with that in sugar, which operates the conversion with other wine, as with the grape. Water is another constituent. As to

the other substances, except tartar, they rather concern the curious in chemistry than the maker of family wines, for some can only be detected by the close scrutiny of the experienced chemist. Little color can be communicated to any of our domestic wines, if the elderberry, currant, blackberry, and black cherry be excepted; but this is a matter of little moment in that which should rather be adopted to please the palate than the eye. If astringency or roughness be in request, that loss may be innocently supplied by the application of catechu. The damson and sloe alone possess it naturally.

The substances necessary to vinous fermentation, the sugar and its sweet principle, the natural vegetal extract, the tartaric acid—in place of which latter the malic acid is often found, which should be dispensed with, and tartar added artificially—and water; these in certain preparations, and in their differences, are the essentials in this class of wines. Sugar is the most important, and its decomposition gives out the alcohol, on which the strength of the wine depends; therefore its quality is of great importance. When the sweet principle and sugar—for they are in union—have disappeared in fermentation, and there is no more vegetal extractive matter belonging to the fruit in the liquid, the wine is a dry wine, and is in its perfect state. If the sugar be in excess, the result is wine and sugar; vulgarly, a sweet wine. If the vegetal extract be in excess, and the fermentation too prolonged, acetic acid will be the product.

The want of attention to the foregoing points often renders the making of dry wines a failure. No yeast should ever be used. If the vegetal extractive matter be wanting, the lees of other wine may be tried; but this is seldom needful, with due care. During fermentation the leaven or ferment is insoluble, and rises to the surface, or falls to the bottom. On restoring this to the surface, the fermentation may be prolonged at pleasure, until the necessary dryness be gained. To attain a sweet wine, the fermentation should be stayed by separating the wine from the ferment, and fining it with isinglass or white of egg. Thus the ferment is separated, and the operation suspended; it may be renewed by restoring the separated matter; if not, a sweet wine remains. It cannot run into acetous fermentation if its leaven be expended; but still there is hazard, and some care necessary, in thus renewing the operation.

Of these acids, sometimes found in fruits—the tartaric, malic, and oxalic—only the first two have any share in the fermentation. Tartar abounds in the grape, and to that its superiority is ascribed. It is wanting in our domestic fruits, or very scantily bestowed. Malic acid is predominant in apples and pears, and they give liquors very different from wine. Crude tartar is best added to the must for domestic wines, not the purified salt.

Care should be taken not to carry on fermentation in new wooden vessels, nor to place wine in them without due preparation. The vegetal extract in the wood will infallibly set the fluid in fermentation, as is well known to the French wine-grower.

The end of the fermentation is the production of the alcohol; and the chemical action involved is well

understood, although the primary force of the ferment is not, nor can it be, so well comprehended. In this respect Nature eludes the efforts of the chemist and physiologist to define correctly her workings, or submit a true definition of the affluities which are continually set in motion by natural force. As regards fermentation, it is true that only the salient points of the chemical changes are understood, but they are sufficient to govern the industry of the fermentation of liquids of every kind, provided all that chemistry has revealed be known to the operator. In domestic wines no just rule has been regarded. Most of the directions are based upon false principles, and display extraordinary ignorance, according to Dr. McCulloch, who has written so well upon the subject; and if not clear to the family makers of such wines, and too scientific for the common concoctors of them, his work still is not the less worthy because the stolid do not perceive its merits.

BRANDE made analyses of the strength of some of the domestic wines, which are appended. The alcoholic strength was per cent. at eighty-nine alcohol and eleven water.

Wines.	Per cent.	Wines.	Per cent.
Grape,	18.11	Orange,	11.26
Raisin,	26.40	Elder,	8.79
Do.	25.27	Mead,	7.32
Do.	23.20	Cider,	9.87
Do. average, ..	25.12	Do.	5.21
Currant,	20.55	Do. average, ..	7.54
Gooseberry, ..	11.84	Perry, average, ..	7.26

Before going into the practical part of the subject, the warning against the use of yeast must be repeated. It is a vile substance when in contact with anything vinous, imparting a base flavor, and is to be altogether shunned. The regulation of the temperature, too, is to be sedulously regarded, that the fermentative process may not proceed too rapidly. The bulk of the must to be fermented, and its exact quality must be well considered; the addition of flavoring substances, and finally, the proper vessels adopted for the different operations.

The fruits most commonly employed for making domestic wines are the elderberry, cherry, raspberry, sloe, damson, quince, strawberry, mulberry, gooseberry, lemon, orange, and two or three kinds of currants. Of these several do not retain their flavor, and are to be rejected on that account. The flavor of the strawberry is not communicated to the wine, nor of the quince or raspberry. These might be infused to advantage nearly at the close of the fermentation of some tasteless must, and thus their flavor be sustained in the wine. The blackberry and mulberry should, as in the instance of grape-wine, be allowed to go into fermentation, skins and all, for the sake of the color. The damson and sloe make a good rough wine, but care must be taken to proportion the sugar to the fruit as to quantity, and by protracting the fermentation, to make a dry wine. By a due admixture of elderberries or currants with sloes and damsons, wines like inferior ports are often easily produced. The proportions vary according to the season. The elderberry may be made to yield an excellent red wine. It possesses enough of the extractive principle to impart a very rich tint, and even a

fine deep color. Tartar should be introduced into the must; and, besides, this berry requires much sugar, as the saccharine principle is scanty.

The gooseberry is known as giving a species of champagne to the list of domestic wines, which are made to effervesce; but, in order to answer, the gooseberries are used in an unripe state. The effervescing property always results from the use of unripe fruit, and will be readily produced by mixing ripe and unripe grapes together; and it is the same with the gooseberry. In general the flavor is bad, and to avoid it, as it is imparted by the ripe fruit, the more unripe should be prepared. This wine should be made with the expressed juice of the fruit alone, and nothing else should be fermented, the skins not being suffered in the must. By this means any disagreeable or peculiar taste is avoided, and the wine, if nearly tasteless, is brisk, pleasant, and perfectly free from any bad flavor. To make this wine, three pounds of sugar, and four of fruit, are allowed to eight pounds of water. Five pounds of fruit would be better, to avoid sweetness, though in complete fermentation; the wine would then be amply strong. No brandy should be added to effervescing wines. Care should be taken in bottling, and the same attention bestowed upon genuine champagne should be bestowed on this imitation wine, which will readily repay the extra trouble. This wine arrives at perfection only in the cellar. Wine made from ripe gooseberries is good for little; but if attempted, the skins must be carefully excluded.

In such wines too little fruit in proportion is used. In currant wines the fruit is always stinted, there being sufficient extractive matter and natural acid to insure, if rightly arranged, a very perfect fermentation. These wines are made too sweet, and pall upon the palate. The proportion adopted is in all cases to be increased as regards the fruit, and the skins to be excluded from the must. The recipes, so manifold, handed about for domestic wines, continually show that the true principles of making such wines are not recognized, although laid down so lucidly by Dr. McCulloch. British champagne is directed to be made by crushing the fruit with a mallet, and a gallon of fruit is to be put to a gallon of water; then brandy is added, and sugar of the species often to be avoided; and brandy is added again in bottling. McCulloch recommends boiling the fruit, in some cases, previous to fermentation. The black currant acquires, by boiling, an agreeable flavor. The success of the plan is remarkable; the more so as, in its natural state and unboiled, it is harsh. The wine made from it much resembles sweet Cape wine. The same improvement takes place in regard to the red and white currant. The boiling should not be protracted. It is always best to boil about a third of the quantity used, and to apply the rest in the natural state. The boiling must not be continued too long, because it tends to precipitate the ferment.

The dried raisin is largely used in making domestic wines; and it naturally must be analogous in some respect to certain foreign wines, because for making them the grapes are not used until they are shrivelled in the sun. Thick, sweet grape-wines are made this way. The process adopted in making raisin-wine in

England has not shown any approach, with the same materials, to the wines made of dry raisins, or such as are called *straw wines*, or some of those of Malaga. In the mode actually adopted here, whether for domestic use, or for the deceptive objects of wine-dealers to mingle with foreign wines, from two to seven pounds of raisins are employed to a gallon of water, common clayed sugar or molasses from half a pound to three or four pounds, and oftentimes from four to six pounds of tartar in the crude state are added. Yeast is not used; still the wine is never well-tasted, and to obviate that, as the bad taste may arise from the skins, cold water is used. It is necessary to apportion the sugar to the tartar. From two to four per cent. of crude tartar is a sufficient addition, giving more when the fruit is sweetest. In regard to the sugar, two pounds to the gallon of the other ingredients will produce a light wine like the white wine of Bordeaux. Three pounds will give the body of hermitage, and four that of Muscat or of Cape Madeira, before their respective doses of brandy were added to them. The sugar added must be apportioned to the quantity in the fruit. If the wine is to be a sweet wine, not less than four pounds to the gallon must be used. The water added must not be out of all proportion to the fruit—which last rarely forms a fourth of the entire fluid—and four pounds to eight of water, and three or four of sugar, supposing no regard is had to the state of the fruit in respect to its ripeness. The vegetal extractive matter in such a case is deficient, as well as the native acid, and this acts injuriously upon the fermentation, and renders it inefficient; the must, consisting of an overplus of sugar and water, cannot thus form wine. Let the principle wanted be increased, and the wine will put on the true character—the dilution of the acid, if the fruit be ripe; and if it be unripe, then the acid and extract being in excess, the operation must fail of fulfilling expectation.

Flavor may be easily imparted to all those wines which want it. Elderflowers, mignonette, clove pinks, for example—or sweet briar, wormwood, ginger, cloves, orris, and the like—will impart, either of them, or perhaps some in combination, a flavor agreeable to the taste of the maker. They are suspended in a bag from the bung-hole during the first stage of fermentation. To please the eye, elderberries, or mulberries, will supply color, or what the French call *vin de fismes*—a color liquor, made near Rheims of a small bitter cherry used for the same purpose, a few drops being sufficient to color a bottle. In Holland, tounsel is used for the same purpose—the *crotum tinctorium* of Linnæus. It is naturally of a blue color, but on coming into contact with an acid it immediately takes a red hue. In France it is said that color derived from woods, as Brazil or logwood, do not long resist the acid of the wines; and, therefore, they find it better to darken the light hue of wines by mingling deep-colored wine with them. This, however, need not deter from the use of such means to suit the eye in domestic wines of English fruit. Bitterness may be obtained by the use of burnt sugar, as well as yellow tints. Cognac brandy for the English market is thus colored in France, where the people use the *pink spirit*.

All vinous operations require great care and sound

judgment. In fining home-made wines, the same management is necessary as in treating the grape-juice with a similar object. The imitation wines made in the household must first be considered in regard to the model immediately in view. If the object be a sweet wine, of which the fermentation is incomplete from the want of sugar in the must, or if its suspension be by design as before described, the operation to be followed is clear.

If the wine be designed to sparkle or effervesce, the cause and mode of acting has been shown; and that briskness is not much in accordance with sweetness. Though generally made of the gooseberry, any other fruit in a proper state of immaturity will answer as well. The use of carbonate of potassa or soda must be avoided, because the gas is almost all disengaged in the first glass on pouring out, before the wine can be drunk, nor has it anything like the effect of carbonic acid gas in the wine. It also deteriorates the taste, and destroys the native acid, replacing it with an alkali.

The Rhénish wines have never been successfully imitated, and for the paramount reason, that their constituent parts are so accurately balanced that they would require great judgment, and much care, in the process; the fermentation must be perfect, and exact proportions be carefully kept in the ingredients. Even then their preservation would require great attention. Fining, racking, and sulphuring, must be had recourse to by hands often not adepts in their use. The dry wines of some strength, imitative of Sherry and Madeira, may be made strong enough without the addition of brandy, which, however, may be added to them by the operator, if he sees it requisite.

Dr. McCulloch recommended that wine should be made from grapes grown in England. The grapes may not ripen in some years, and in an agricultural view it is profitless; but wine is continually made by cottagers in Sussex from the grapes grown in front of their houses, and some species ripen a full month before others. The white muscadine, the two varieties of the chasselas, the black Hamburg, and others, are of this class. But to make domestic wine from the grape in England, does not demand that the grape should reach the maturity required for its wines, as the term is generally understood. A crop of grapes is certain, if not always a ripe crop. A compound artificial must can be made from the admixture of sugar with the extractive and other matter of the fruit, which, undergoing a regular fermentation, forms a perfect wine, as applicable to the grape as the gooseberry. The experiment has been tried and found successful, and domestic wines made this way declared excellent. Three pounds, or less, of sugar to the gallon, with the hardest grapes, produce a wine of the strength of red hermitage, not void of flavor, but the reverse. Dr. McCulloch mentions the proportions he found needful, both of sugar, water, and other substances necessary for the purpose. He kept some of the wines twenty years, and found them as little liable to destruction as the wines of France.

The want of judgment, the haste, the non-comprehension of the chemical principles upon which wine is made from domestic fruits, the want sometimes of a clean palate on the part of the maker, and the aban-

donment of a nice operation to the hands of servants and old housewives, have caused great mistakes in the manipulation of these wines. Dry wines of the first quality do not require that maturity of the grape which is so necessary to those which are sweet. In the first case sugar can be added; but the customary notion of the ignorant in this, as in other cases, often prevails, and the neglect of the green grape for the green gooseberry is a striking proof of it. Nor is this all; for it has been proved by chemical examination, that the tendrils, shoots, and even the leaves of the vine themselves, possess exactly the same qualities as the crude fruit. Experiments were in consequence instituted in France, to try if they would not answer for the purpose, and they were satisfactory; but there, where the fruit was to be had in any state, the matter naturally terminated; while in England it was different. The success of the attempt was decisive, on adopting the management had recourse to in treating wine from other unripe fruit. Only young or half-green vine leaves are selected, together with the tendrils. The old leaves are not proper. The month of June is the right season to pluck them. The vines for the purpose may be planted anywhere, and suffered to run up unpruned. Close imitations of the sparkling wines of Champagne and of St. Peray have been made this way, and none were made that were not as good as the ordinary sweet wines of the Cape. If the wine is too sweet from want of the vegetable extract in a sufficient quantity, a fresh infusion will reinstate the fermentation. The wine of a defective year in goodness, may be renewed the next season. The leaves should be infused sometime before they are used, yielding their virtues more readily to hot than cold water without any material difference in the result. Half a pound of crude tartar, or more, within a pound, to two gallons of must, is useful. The expense of the sugar here is nearly the whole incurred, and a single vine will supply a family, as the leaves are successive.

A few specific directions under the scientific authority before mentioned:—The cask measure being supposed ten gallons, will illustrate the foregoing principles; those adapted to the lands of the vine being kept in view as guides, where any difficulty may occur. In a tub or vat carefully cleaned, that has a capacity for fifteen or twenty gallons, forty pounds of the gooseberry of the green Bath kind are introduced, avoiding any that are ripe. Reject the unsound, and remove the blossom and fruit-stalk, or their remains. The small berries may be separated by a sieve. The fruit is to be bruised into the vat by a pressure sufficient to break the skins, without fracturing the seeds or compressing it too much. Four gallons of water are then poured in upon the fruit, and the whole is carefully stirred and compressed with the hand, until the juice and pulp are separated from the solid matter. The materials must rest for ten or twenty-four hours, and then be strained through a coarse bag with as much force as can be easily applied. A gallon of fresh water is to be added to the mash, to remove any soluble matter remaining. From twenty-five to thirty pounds of white sugar are to be dissolved in the must

or juice thus obtained, and the mass of fluid increased by more water to ten gallons and a-half. This difference in the weight of the sugar is to balance any in the quality of the fruit, the discovery of which difference must depend upon the judgment of the operator. Old haphazard receipts gave forty pounds of sugar, which of course make a sweet wine, continually failing in effervescence on that account. The must is next to be placed in a tub or vat, over which a blanket is thrown, and a board over that, and the whole kept in a temperature between 55° and 60°, to remain from twelve to twenty-four hours, according to the state of the fermentative process. It is then to be drawn off into a cask until the fluid nearly reaches the bung-hole, so that the scum which ascends to the surface may overflow, and be thrown out. As the fermentation goes on, and the bulk of the liquid diminishes in the cask, the superfluous must made for that purpose must be poured in, so as to keep the liquid always near the bung-hole. When the fermentation diminishes still more, which may be judged of by the reduction of the hissing sound, the bung is driven in, and a hole bored on one side of it, into which a wooden peg is put, and in a day or two taken out, in order that the gas within may have vent. It is then restored and reopened to let the gas again escape, until, there being no longer any danger from the expansion, it is tightened for good. The wine is to be kept over the next winter season, in a cool cellar, and on a clear sharp day about the beginning of March, if fine, it is bottled; if not fine, or to insure its fineness, if doubted, at the end of December it is decanted into a fresh clean cask, to free it from the lees, which, if the wine be too sweet, instead of drawing it off, should then be stirred up in it, increasing the temperature to renew the fermentation. When drawn off, it is fined with isinglass; and if not clear, the operation is repeated in dry, clear, cold weather as before, and bottled in March, and not later. Such a wine is brisk like champagne, and similar in quality, but stronger, differing in little but the flavor. Sometimes the wine will be still, like sillery, or sweet, without close attention to the process; at other times it will be dry. If sweet and still, it may be remanufactured the next season by renewing the fermentation, and repeating, under the addition of fresh juice or must, the former treatment. If it be dry, it remains so, and may be drawn off into a sulphured cask, and then fined and bottled. Any peculiar and not agreeable taste, during the first year, will go off by age. Such wines are best when drunk at five or six years old. In making the foregoing wine, the mode in managing grape-wine—fermenting the husks or skins as well as the juice with the sugar—may, on the other hand, be adopted in the earlier stage of the operation. The rapidity of the fermentation in this way is much increased; the wine, stronger and less sweet, will gain more flavor. Crude tartar, to the extent of six ounces to the ten gallons, is sometimes added. Sweetness with briskness, though the latter quality is hazarded, may be had by using sugar to a greater extent under forty pounds. Brisk domestic wines are not durable nor strong, and must be drunk very early from want of the capacity for keeping. Effervescence without sweetness

is obtained by increasing the fruit, as in the proportion of fifty pounds of fruit to thirty of sugar.

The wine made from unripe currants, under the same general process as the former, requires that the stalks be separated with care. The must of this fruit is much easier to manage than that of the gooseberry, and it is far better calculated for brisk wine, and less likely to carry a bad flavor.

Nothing but the pure must is introduced into the cask—not a particle of the mash. If, in the fermenting in the vat, the scum, crest, or head, called the *chapeau* by the French, be tainted with sourness or mustiness, it must be at once removed; and when the fermentation of the mash does not take place with the must, the latter may be at once introduced into the cask.

Mature gooseberries and currants are made to produce dry and sweet wines by the foregoing modes. In sweet wines the fruit should not be above forty pounds; if in dry, it should be carried to sixty. The sugar should be full thirty pounds, unless a strong wine is desired, when forty pounds must be employed.

Wines from elderberries are made with the same proportions of ingredients as the former kinds, and in the same manner. If boiled fruit is taken—an operation which relates almost wholly to the black currant—the fruit must only be brought to the boiling point of the water, and the burning of it at the bottom of the vessel must be guarded against. Wine from the mature grape in this country it is not worth while to manufacture, as too few grapes ripen to make it any other than an object of curiosity, and the mode of treatment of them, described in the preceding pages, contains all that is necessary upon the subject.

It is probably due to McCulloch that it was ever known that domestic wines could be made from immature grapes, vine tendrils, the young leaves, and the thinnings of the branches in places where vines are grown under shelter, in different stages towards maturity, no matter how different in species. No part of the vine need be feared as communicating a bad flavor. If the immature grapes be those grown in the open air, they should be taken just at their first tendency to ripen. The proportions and treatment are similar to those recommended for the gooseberry, but the husks may always be fermented in the vat with the must. Except in not breaking the seeds, no care need be taken about not bruising the fruit. The fermentation will be slow; but no obnoxious yeast is to be employed. Patience is necessary, but the operation will not ultimately be less effectual. Elevation of the temperature will excite it, if languid; as will also agitation of the cask, or omitting to replenish the fluid at the bung, so that the scum may remain upon the liquor.

The wine made from the young leaves, tendrils, and even young shoots, may be taken at any period from vines cultivated for this object, from which fruit is not expected. If the claret vine—*Clairette rouge de l'Herault*—be cultivated for the purpose, the wine will be of a red color. The leaves should be young, and sixty or eighty pounds should be introduced into a vat. In the vicinity of a large town they should be first washed, to clear them of sooty particles from the impure atmosphere. Seven or eight gallons of boiling water

should then be poured upon them, and left to infuse for twenty-four hours. The water being poured off, the leaves are pressed in a press of considerable power, washed with an additional gallon of water, and again pressed. Sugar, from twenty-five to thirty pounds, is then to be added to the mixed liquors, and the whole made up to ten gallons and a half, when the same process is to be pursued as in the case of gooseberry wine. The water soon cools down to the usual temperature, it being used hot in order more effectually to extract the soluble part of the plant or fruit. These proportions are for brisk wines, which, if mismanaged, will fail of due effect. In the case of sweet wines of the same substances, from thirty-five to forty pounds of sugar must be used. As soon as the first fermentation has subsided, the wine is racked into a sulphured cask and fined. If it tend to a renewal of the fermentation, it must be racked and fined again, and even a third time. When perfected, the wine may remain in the cask as long as is desired. For dry wines the proportion of fruit to the sugar is to be the largest of all. The bung must be left open, and the fermentation, if sluggish, must be increased by heat and agitation. If the wine continues too sweet, it may be bunged down until the next spring without fining, and then the fermentation must be renewed by adding fresh must. As soon as it has become sufficiently dry, it must be fined into a sulphured cask, and again fined before bottling. The dry and sweet wines of this kind should be kept five years to be in their highest perfection. The brisk wines are drunk after being six months in bottle, and are good to their third year. If they lose their briskness, they become dry, something like the Moselle or Rhine, and will keep indefinitely.

Wines, if they can be so called, are also made of dried substances, as ginger. They are composed of sugar and water, fermented with yeast and flavored with ginger. These are rather drinks than wine. The last are made by fermenting substances which possess little or none of their own extractive vegetal matter. Three pounds of moist sugar, a gallon of water to two ounces of bruised ginger are boiled, skimmed, and set to ferment with a yeast toast, flavored with a lemon to each gallon, or a little balm, and then bunged up. In about two months it is fit for drinking, having been fined with isinglass.

Mead, a very ancient domestic wine of honey, is made with sixty gallons of pure soft water, and seven gallons and a half of clarified honey, of which mellitose—see SUGAR, Vol. II. p. 966—is the sweet principle. In a copper of thirty gallons capacity, having mixed the honey and water, boil it down to one-fourth, then let it off, and boil the other moiety in the same manner; and when thus reduced fill up the copper with what was boiled first, and continue ebullition and filling up until the copper will contain half the liquor, all the rest having evaporated. The liquor must not be skimmed, but the scum must be well mingled with the liquor while seething, by means of a jet. When this is done it is drawn off into under-backs by a tap in the copper, and the fluid falls to the temperature of new milk. Then it is turned up and fermented in the vessel, where it forms a thick head. When it has

ceased to ferment it is closed from the air, and bottled at the end of six months, having been well worked and kept in the same cellar temperature as it had before. Aromatic flavors are often added by mixing elder or rosemary, marjoram flowers, and the like; or cinnamon, cloves, or other spices, during the process.

Raisin wine was manufactured light and dry in England of a superior kind, by Mr. AIKIN, secretary to the Society of Arts in 1829. Dr. M'CULLOCH censured the mode in which it is generally attempted to be made, and noticed the failure which is naturally to be expected from the use of molasses, coarse sugar, and the nauseous yeast of beer, which can never be rendered vinous. He would have the native acid neutralized, and with all domestic wines use crude tartar. Mr. AIKIN's wine was produced from Muscatel raisins. These, it is obvious, being sweet and dry, were not very different from some of the shrivelled and dried-up grapes with which wines are made in the South of Europe, as in the example of straw wines, for which the grapes are kept on the vine till shrivelled, and then further dried upon straw, giving a thick must, scanty in proportion to the produce, in a state of the grape so over-mature. Muscatel raisins are imported in boxes of twenty pounds weight. The fruit kept in the warehouse or shop unsold for above a year, is less approved by purchasers than when new, the rich pulp becoming mixed with the saccharine concretions. The extractive matter or gluten in the raisin is more than sufficient to ferment its sugar, and only from one-tenth to a third of the weight of the raisins is added. Cane sugar should be avoided in the unrefined state; if used it should be loaf. Sugar from honey or starch would be best, as unrefined sugar of the cane taints the wine. The raisins, without the stems, are chopped fine on a board, in the mode adopted with minced meat. Three pounds of raisins and one pound of sugar, were used to an ale gallon of water. The next process is mashing or maceration. If the former mode is adopted, the chopped raisins are placed in a tub, and hot water, a quart to four pounds of fruit, poured over them—the water not heated above 120°—to extract the mucilage. The whole is then stirred with the hand, no lumps being left, and placed in a sieve over a tub a short time to drain; this operation is repeated a second time throughout. The clamminess of the mass is by this extracted. The water for a third mash is poured on at 160°. The liquor now begins to be acidulous, with little sweetness. Three-fourths of the mash being made and tasted, to discover if it be sufficiently astringent, the stems or stalks, in part or all, are used, according as more or less astringency is intended. Hot water is poured upon the must, and the whole is well pressed by the hand. The three first mashes are now thrown into the tun, and the sugar, with as much of the last mash as will bring the must to its due proportion of one ale gallon to three pounds of fruit and one of sugar. The operation so far requires four or five hours; the temperature of the must is about 70°. The liquor soon ferments according to the atmospheric temperature and its treatment, but generally within thirty-six hours. The scum is either duly removed, or suffered to remain till the wine is drawn off. If the fermentation is languid, the cover is kept on the tun

and the scum stirred into the liquor; if too rapid, the cover is taken off and the scum removed as it rises. The must is thus become vinous, and is transferred to carboys, or stone-ware barrels, holding six or seven gallons. Safety tubes of glass are placed in the bungs, and on the second day an inch of quicksilver in the tube, to exclude the air. The bungs are covered with a cement consisting of wax and rosin. Carbonic gas bubbles through the quicksilver for some weeks, when it ceases. The wine should remain for the summer in the carboys, or barrels, if the latter be used. The wine thus made in April should be bottled in March, or if made in October, be bottled in September. The wine is not fined, for a light dry wine the inventor thought would be injured by being deprived of its tannin. After a year in bottle the wine had a bouquet like elderflower. As the wine is not fined it is decanted with care to keep it clear. It is of a pale yellow color, but in a short time deepens to the tint of Buccellas, having a flavor something like prussic acid at uncorking, which disappears. If, in place of mashing, maceration is applied, putting the chopped raisins and sugar into cold water, a higher colored wine is obtained, the fermentation is slower, and it is destitute of the elderflower bouquet, acquiring a taste from the husks of the raisins; but often this second mode of treatment answers well. It is sometimes twenty days under fermentation. Tartar is often added in making this kind of wine, but it often fails to be good—generally from the use of molasses, cane-sugar, and yeast.

Makers of domestic wines, it must be repeated, fail from not, before commencing their attempts, becoming perfectly acquainted with the mode of making foreign grape-wine, and the principles upon which it is done, which are applicable to all domestic wines, almost without exception. They are scarcely ever what they are capable of being made. In the evidence on the wine duties, before a Committee of the House of Commons, Mr. A. WALKER and Mr. J. FRITH were examined. They dealt in wine, home-made, of all kinds, and some bearing foreign names. The wholesale price by the hogshead was five shillings per gallon. They make sixty-five thousand gallons, of which ten thousand are British port and sherry. It is estimated that six hundred thousand gallons of these wines are made. Port is imitated from the black cherry; champagne from French grapes; port, partly too with French grapes and raisins; and Cape or Pontac, with bottoms of Oporto and Spanish wines. Spirit is added to them all. Some champagne, home-made, is from rhubarb and gooseberry. It is averred that any light wine may be made to pass for home-made champagne, by means of sirup and carbonic gas, applied as if to aerated waters. However this may be in practice, Dr. M'CULLOCH so well explained the process of making these wines, that success is sure wherever the guide he has left is followed; and if the domestic manufacturer be not successful, it is not for want of the soundness of the principle, but of the practical action arising from its knowledge.

WINE MEASURES.—The imperial gallon wine measure which superseded the old contains ten lbs. avoirdupois of distilled water, or 277.274 cubic inches. The old wine gallon was equal to two hundred and thirty-one

cubic inches, the ratio being nearly as six to five, or more correctly as one to 0·833111. The imperial

wine-pint is 34·65925. The old English wine measures were:—

Tun.	Pipes.	Punchoons.	Hogsheads.	Tierces.	Barrels.	Rundlets.	Gallons.	Quarts.	Pints.	Quartons.	Cubic Inches.
1	2	3	4	6	8	14	252	1008	2016	8064	58212
	1	1½	2	3	4	7	126	504	1008	4032	29106
		1	1½	2	2½	5½	63	252	504	2016	14553
			1	1½	2	3½	42	168	336	1344	9702
				1	1½	1½	31½	126	252	1008	7270·5
					1	1	18	72	144	576	4158
							1	4	8	32	231
								1	2	8	57·75
									1	4	28·875
										1	7·219

Wine measures differ greatly in the European wine-making countries, and give much perplexity in conducting operations of any kind in regard to them. Thus a tun is two pipes; three punchoons, four hogsheads; six tierces, two hundred and fifty-two old English gallons; and one thousand and eight quarts, two thousand and sixteen pints. The following are some of the more common measures:—

	Old Gallons.	New Gallons
Tun,.....	252	210
Pipe of Port,.....	138	115
Do. Carcavellos, Lisbon, Bucellas,.....	140	117
Do. Madaira,.....	110	92
Do. Sicilian, Marsala,.....	112	93
Do. Vidonia, Teneriffe,.....	120	100
Butt Mountain,.....	126	105
Do. Malaga,.....		
Do. Sherry,.....	120	100
Hogshead, Claret,.....	57	46
Do. Tent,.....	63	52
Ohm Rhenish,.....	36	30
Do. Aix-la-Chapelle,.....	—	35
Do. Cologne,.....	—	41
Do. Heidelberg,.....	—	29
Do. Cassel,.....	—	43
Do. Frankfort,.....	—	39

The French measures are the litre and hectolitre. The first contains 61·0280264 cubic inches; the second, 3·531714693 feet English; or the litre is equal to 2·113 pints old English wine measure, and the hectolitre to 26·4 old English gallons, or to 22·01 gallons imperial, and the litre to 4·5432. Therefore, 100 imperial gallons are 454·3200 litres. A pipe of port contains 522·3680 litres; a butt of sherry, 490·6656; a hogshead of claret, 208·9872, and an ohm of Rhenish 136·2960. In France, let the name of the cask or measure be what it may, the stranger asking the number of litres, is at once answered—the litre being the legal standard.

FRENCH WINE MEASURES WITH OLD ENGLISH.

Litres	Cubic inches	Imperial pints	Old wine pints	Oz. of water, troy.
1 =	61·028	1·7608	2·11353	31·104
2 =	122·056	3·5216	4·22706	64·208
3 =	183·084	5·2822	6·34059	96·312
4 =	244·112	7·0430	8·45412	128·416
5 =	305·140	8·8038	10·56765	160·520
6 =	366·168	10·5646	12·68118	192·624
7 =	427·196	12·3253	14·79471	224·728
8 =	488·224	14·0861	16·90824	256·832
9 =	549·252	15·8469	19·02177	288·936

In some countries a troublesome variety prevails in measures of the same name. In Sweden, the ohm is 139·019 litres, or 30·543 gallons imperial; at Strasburg it is only 46·093 litres, or 10·146 gallons.

The measures for wine in Spain are commonly arrobas, of which sixteen make a mayo; twenty-seven mayos, a pipe; thirty pipes, a bottle—the last equal to one hundred and twenty-seven and a half old English gallons, or one hundred and six imperial. But the measures of the same name differ in different provinces. The arroba of Valencia contains 11·786 litres; of Malaga, 15·850; of Spain and the Canaries generally, 16·073. The cantaro of Alicante is 11·554 litres, or about three gallons, and the tonelada is one hundred cantaros; that of Arragon, 10·313; of Oviedo, 19·236. The cagna of Barcelona is 123·756; the gerra of Minorca, 12·063; the mayo of Galicia, 161·991; the quartin of Majorca, 27·131 litres, or 7·168 old gallons.

In Portugal, the almude is 25·480 litres; of Lisbon, 16·541; of Oporto, twenty-one make a pipe; at Lisbon, thirty-one, or one hundred and forty old English gallons. At Figueras the almude is 4·75 English imperial gallons; at Viana, 5·5. All these are in use in Portugal; besides which, they have potes, canadas, quartillos, basils, and toneladas; this last two hundred and thirty-one imperial gallons.

In Germany the ohm varies, at Hanover and Hamburg it is thirty-two imperial gallons; on the Rhine only twenty; at Ratisbon the bergeimer—about nineteen imperial gallons, and the same at Munich—seven and a half only; at Vienna it is ten and a half imperial gallons. The ohm at Basil, in Sweden, Dantzic, and Strasburg is a different measure from the German ohm. The ohm at the Cape of Good Hope is thirty one and two-thirds; the eimer of Leipzig, twenty and a half old English gallons, and at Dresden eighteen only; at Antwerp the aum or ohm is forty-two old English gallons.

The Russian wine-measure is the vedro of 2·705 imperial gallons; three vedros make an anker; six ankers, an oxbast; two oxbasts, a pipe, or 75·320 imperial gallons.

The Hungarian measures are, the antheil of 11·125 imperial gallons; the great and little eimer—the first equal to 16·140 imperial gallons, and the second to 12·515.

The other European wine measures are of little moment comparatively. In Italy they are numerous. The oke in Greece is two pounds, three ounces, five drachms, avoirdupois; and the alma of Constantinople, 1·150 imperial gallons.

Mr. CYRUS REDDING kindly tendered some valuable matter, which the Editor has incorporated in the preceding details.

ZINC.—*Zinc*, French; *Zink*, German.—It is only from the middle of the sixteenth century that zinc has been known as a metal. Its ores were known from a very early date, and were spoken of under various names; but the first account which is recorded of the term *zinc* being used in reference to the educt from the calamine or cadmia of the period, is that of ALBERTUS MAGNUS; and the first who characterized it as a distinct metal was PARACELSUS, about the year 1530. For a long time afterwards, however, the knowledge of this substance was almost entirely confined to alchemists, who prized it highly on account of the property which it was thought to possess of transmuting copper into the more precious metals. It was owing to this imaginary property that the metal was long termed *counterfey* or *counterfeht* by the Germans. The present name seems to be derived from the word *zinken* or *zacken*, the German for nails or spikes, because, in preparing brass, a portion of the ore, on being sub-

mitted to a preparatory roasting, often assumed such forms. The synonym *SPELTER*, which is now so much used in commercial language, is derived from the terms *spialder*, *spialter*, et *cetera*—terms which were introduced along with the first portions of this metal imported from India.

That the ores of zinc were known to the ancient Greeks and Romans, is attested by the accounts which DIOSCORIDES, STRABO, and PLINY give of one of them, or perhaps of several of them under one generic name; and likewise by the fact that in the time of these writers or at a later period, articles are known to have been produced in a kind of brass or bronze, the analyses of which clearly indicate the presence of zinc in greater or less proportion. The following analyses of different varieties of brass, dating from about the beginning of the Christian era, are given by PHILLIPS as demonstrating this fact indisputably:—

		Copper		Tin.		Iron.		Zinc.		Lead.
Large brass of the Cassia family, B.C. 20	....	82.26	....	—	....	0.35	....	17.31	....	—
Large brass of Nero family, A.D. 60	....	81.07	....	1.05	....	—	....	17.81	....	—
Titus, " 79	....	83.04	....	—	....	0.50	....	15.84	....	—
Hadrian, " 120	....	85.37	....	1.14	....	0.74	....	10.85	....	1.73
Faustina, jun., " 165	....	79.14	....	4.97	....	0.23	....	6.27	....	9.18

Of many other bronze articles analyzed by PHILLIPS, none of them, known to have been produced anterior to the year 20 before CHRIST, were found to contain zinc as a constituent, tin being the material employed instead of that metal. The earth which was used in those early days for the purpose of forming an alloy with copper was termed *cadmia*; but it is evident that by this substance was not meant an oxide or silicious oxide of zinc, as at the present day, but any mineral, whether oxide or carbonate, that contained a large proportion of that metal, notwithstanding there being other metallic compounds associated with it. The alloy so prepared was known as *aurichalcum*, which was then recognized as a purer copper than the ordinary metal, and hence was more esteemed. The dross or oxidized portion sublimed from or remaining in the furnace after the alloy was drawn off, was likewise known by the general term *CADMIA*, but was distinguished by some particular designation, according to its color, form, or consistency. In later times this compound was distinguished at Rammelsberg as furnace calamine—*ofenbruch*—when it was discovered that it could be employed instead of native calamine in the manufacture of brass. Another substance called *TUTIA*, which seems to have been analogous to *cadmia*, or at least to have been a compound also rich in oxide of zinc, is spoken of in writings of the eleventh and subsequent centuries as having been employed for the manufacture of brass. ZOZIMUS, who is supposed to have written about the fifth century, states, that to make brass, cyprus copper must be melted and pounded *tutia* strewn upon it. According to ALBERTUS MAGNUS, the celebrated alchemist HERMES taught the method of making copper of a gold color by introducing pounded *tutia* into the melted metal; and ALBERTUS leaves no doubt of the nature of this *tutia*, for he states that it is not a native mineral, but an

admixture produced in the furnace when copper ore is melted—thus showing that evidently it was a sublimed oxide of zinc mixed with other ingredients, and analogous to the furnace calamine or *ofenbruch* of a later period. The discovery that this sublimate could be substituted for native calamine in the production of brass, is said to have originated with ERASMUS EBENEZER, a German, towards the middle or first quarter of the sixteenth century. The discovery was greatly esteemed, as up to that period the refuse matter from the furnaces of Rammelsberg were cast aside as useless. Doubtless the period intervening from the time of ALBERTUS MAGNUS to that of PARACELSUS gradually developed facts resulting in a more comprehensive knowledge of *cadmia*, *tutia*, and the other substances containing oxide of zinc, and leading as a natural consequence to the isolation of the metal. Indeed, the former of these writers distinguished the principle in the earth which was used to convert copper into brass as *marcasita aurea*, a term which might be qualified as meaning the metal of this earth, though properly it was understood at the period as a mercurial ore, probably a sulphide of mercury. This *marcasita*, of which MAGNUS speaks as superior to the other ores of zinc, was found at Goslar; but that of which PARACELSUS wrote was stated to be produced at Carinthia. By AGRICOLA, however, who wrote about the year 1550, reference is made to the Goslar product alone, which he designates as *liquor candidus* or *counterfey*; and FABRICIUS, who died in 1571, conjectures that *stibium* is what the miners call *cincum*, a compound that could be melted but not hammered.

From these different statements it will be seen that the knowledge of zinc, even for a long time after its recognition as a distinct metal, was exceedingly meagre; and in point of fact very few of the chemists of that period could obtain even samples of

it, owing, as it is alleged, to the great hopes entertained of it as an alchemical agent, and the consequent prohibition by Duke JULIUS to sell it or make it generally known. However this may be, the first certain account of its production at Goslar was given in 1617, by LÖHNEYSS, whose note in reference to it runs thus:—When the people at the melting-house are employed in melting, there is formed under the furnace, in the crevices of the walls, under the stones where it is not well plastered, a metal which is called zinc or *counterficht*, and when the walls are scraped the metal falls down into a trough to receive it. This metal has a great resemblance to tin, but it is harder and less malleable, and rings like a small bell. It is not much valued, and the servants and workmen collect it only when they are promised drink-money. They, however, scrape off more of it at one time than at another; for sometimes they collect two pounds, but at others not above two ounces. This metal by itself is of no use, as, like bismuth, it is not malleable; but when mixed with tin, it renders the latter harder and more beautiful, like English tin. This zinc or bismuth is in great request among the alchemists.

BECKMANN KENKELL is accounted to have been the first who procured it directly from calamine in 1741. After him LAWSON is stated to have succeeded in extracting it from the ore, though no account of his researches exist. VON SWAB, a Swede, obtained it by distillation from calamine in 1742; and almost contemporary with him MARGGRAF likewise discovered a process for the same purpose in 1746. It is stated by WATSON in his chemical essays, that in 1743 a manufactory for the production of this metal was established at Bristol, by CHAMPION, and was carried on by his successor, EMERSON, who established another in the neighborhood. It appears, however, that the wants of Europeans, as regards this metal, were supplied from China and India, through the Dutch, and probably the Portuguese, the imported articles bearing the title *tutenague*, or Indian tin. RAYNAL records that the Dutch East India Company purchased annually at Palimbang a million and a half pounds of this metal; and the Danish Company at Copenhagen, in 1781, as much as one hundred and fifty-three thousand nine hundred and fifty-three pounds. It appears, however, that between the above date and 1820 the production of zinc must have greatly increased, as it is recorded that at the latter date spelter or zinc was imported into England from Silesia, to be again exported to India to supply the place of the *tutenague*, formerly imported from China. The Silesian zinc was analogous in composition to the Chinese product, as will be seen by the subjoined figures:—

	Zinc.	Lead.	Iron.	Sulphur.	Sand.
Silesian zinc,	98.32	1.40	—	0.18	0.10
Chinese tutenague, 97.63	0.33	1.90	0.14	—	—

The quantity exported from England to India almost balanced the total amount of her imports, until about 1830, when the quantity retained for home consumption began to be increased annually, so that in 1851 the amount thus utilized reached eleven thousand two hundred and sixty-two tons, while the quantity imported in the same year amounted to eighteen

thousand six hundred and twenty-six tons, whereas the exports to India remained nearly the same. At present Silesia is the great seat of the manufacture of zinc, containing the largest works of the kind in the world, and producing as much as fifty-three per cent. of the total yield of all countries. Belgium, including more especially the works of the Vieille Montagne Company of Liege, ranks next, and produces about thirty-three per cent.; Poland and Cracow furnishes ten and a quarter per cent., and England the remainder.

The application of zinc within the last twelve years has been very much extended, not only for use in brass foundries, but in several other departments, such as in galvanizing iron for light roofing and for fencing, and in fact for all the lighter kinds of iron which have to be exposed to the air; for the base of electro-plated articles, for paint, and various other applications.

OCCURRENCE OF ZINC.—This metal is never found in the native or virgin state, but always combined with oxygen, sulphur, and salt radicals. Ores of zinc are met with in almost every country, though not to such an extent in many of them as to render them particularly important in a metallurgical point of view. The most remarkable deposits of these ores hitherto discovered are those in New Jersey in the United States, where almost every variety of the natural combinations of zinc are met with. They exist in considerable quantities in Siberia and on the continent of Europe, more especially in Silesia, Hungary, Carinthia, Saxony, Belgium, Sweden, and France; also in England and Scotland, and some parts of Ireland. The most famous localities where the deposits occur will be mentioned presently in specifying the particular ores of zinc.

ORES OF ZINC.—The most important ores of zinc, not only as containing more of the metallic element, but also as affording greater facilities for its extraction, are the oxide, carbonate, sulphide, and silicates.

OXIDE OF ZINC—SPARTALITE—red oxide of zinc, zinc oxide ferrifere; zinc erae; zinkit.—Generally this ore is met with in the amorphous state, but it is occasionally found crystallized in forms of the rhombohedral system, the crystals appearing colorless or yellowish-red, according to the purity of the compound; their lustre is adamantine, appearing translucent on the edges, having a cleavage parallel to the base and one of the sides, a conchoidal fracture, and a specific gravity equal to 5.43 to 5.52. Crystallized oxide of zinc is infusible before the blowpipe, though it phosphoresces strongly; with borax and phosphorous salt the presence of manganese is indicated in it, while that of zinc is shown by the green color produced in the assay, when it is moistened with nitrate of cobalt solution, and subsequently heated to strong redness. The powdered crystals, as well as the amorphous substance, dissolves readily without effervescence in nitric acid. Its composition is—

	Whitney.		Hayes.	Berthier.
Oxide of zinc,	94.45	96.19	93.48	88.0
Oxide of manganese, trace		3.70	5.50	
Franklinite,	4.49	—	—	12.0
Oxide of iron,	—	0.10	0.80	
Loss by ignition, &c.	1.06	0.01	0.22	
	100.00	100.00	100.00	100.0

CARBONATE OF ZINC—*calamine*; *zinc carbonaté*, *Galmei-Smithsonite*; *zinc spar*.—This is by far the most important ore of zinc, and that from which the metal is chiefly extracted; it is more diffused than any other, and offers, like the oxide, peculiar facilities for smelting. Calamine is usually found in a crystallized state, in concretioned and compact masses, and in pseudomorphic forms. The crystallized variety when pure has a vitreous, inclining to a pearly lustre; is colorless, white, grey, green, or brown, according to its freedom from extraneous matters. Its crystalline form is that of the rhombohedron, with a cleavage parallel to its faces.

Its fracture is uneven or imperfectly conchoidal; its streak white, and its specific gravity 4.34 to 4.45. The ore is infusible before the blowpipe, but affords a white sublimate of oxide of zinc when it is heated on the charcoal, and which is yellowish while hot, and becomes white on cooling. By moistening the assay with a solution of nitrate of cobalt, and then heating, the green color peculiar to zinc under such treatment makes its appearance. It is readily soluble in acids with the evolution of carbonic acid, and in an excess of caustic potassa. The following analyses of a few samples of the mineral indicate its composition:—

	Smithson.		Karsten.			Berthier.
	1	2	3	4	5	6
Oxide of zinc,	64.8	65.2	57.76	64.53	64.36	60.7
Carbonic acid,	35.2	34.8	35.62	35.47	35.14	35.0
Protoxide of manganese,	—	—	6.62	—	—	—
Oxide of lead,	—	—	—	—	0.50	—
Oxide of iron,	—	—	—	—	—	4.3
	100.0	100.0	100.00	100.00	100.00	100.0

Samples 1 and 2 in the preceding table represent calamine from Somersetshire and Derbyshire; 3 is from Nertschinsk, 4 from Altenberg, 5 from Brilon, and 6 from Taina in Siberia.

Annexed are a few analyses of other samples of

calamine more manganiferous than the foregoing. Number 1 specimen represents the calamine in yellowish white crystals from Altenberg; No. 2, light green crystals from Nirm; No. 3, dark green crystals; and No. 4, calamine from Nertschinsk:—

	Monheim			Kobell
	1	2	3	4
Carbonate of oxide of zinc,	81.92	85.78	74.42	96.00
Carbonate of protoxide of iron,	1.58	2.24	3.20	2.03
Carbonate of protoxide of manganese,	6.80	7.62	14.98	—
Carbonate of oxide of lead,	—	—	—	1.12
Carbonate of lime,	1.58	0.98	1.68	—
Carbonate of magnesia,	2.84	4.44	3.88	—
Silicate of oxide of zinc,	1.85	—	—	—
Silica,	—	0.09	0.20	—
Volatile matter,	—	—	0.56	—
Loss,	0.43	—	1.08	0.85
	100.00	101.15	100.00	100.00

Very frequently the silicated oxide of zinc and the carbonate are confounded under the title calamine. Two principal classes of calamine are recognized, namely, ordinary white calamine, which may be a carbonate or a silicate of the oxide, containing but a very small proportion of ferruginous matters, and the *red*, which differs from the foregoing, but only by its containing more hydrated sesquioxide of iron or its salts.

The following are analyses of red calamine by JOHN:—

	From Hindipkar.	From Beuthen.
Oxide of zinc,	39.00	35.00
Carbonic acid and water,	15.00	{ 24.37
Oxides of iron, manganese, lime, and silica,	46.00	{ 10.63
	100.00	3.000

Calamine, as well as *blende*, is found in two geological formations—the one is the carboniferous or mountain limestone, in which it occurs in veins accompanying galena; and the other the magnesian limestone formation of English geologists, the Alpine limestone of the French, and the *Zechstein* of the Germans, in which it is disseminated in small veins forming a network in the mass, not more than a few inches in thickness, except where several intersect, when it sometimes increases to

as many feet. Explorations for lead and zinc are carried on in England, wherever the mountain or metalliferous limestone exists; but the principal seats of operation are in the neighborhood of Alston Moor in Cumberland, of Castleton and Matlock in Derbyshire, and in Flintshire in Wales. In the magnesian limestone the explorations for calamine are prosecuted chiefly on the flanks of the Mendip hills, near Bristol; and the mineral is excavated by means of numerous small shafts and levels. Calamine usually occurs in beds and veins, associated with Smithsonite galena, blende, and other minerals, in the crystalline slates, transition rocks, the coal formations, the muschel kalk, and oolite formations. It is found at Altenberg and Nirm, near Aix-la-Chapelle; at Iserlohn and Brilon in Westphalia; near Tarnowitz in Silesia; at Raibel and Bleiberg in Carinthia; in the Banat; at Miedziana Gora in Poland; Dognazka, Rezbanya, and Saska, in Hungary; at Kucsiana in Servia; Tschairski in the Altai; Nertschinsk and Nischn Tagilek in Siberia; Chessy in France; in Belgium; in several places in the United States, especially in Jefferson County, and many other localities.

SILICATE OF OXIDE OF ZINC—*Smithsonite*, Phillips; *zinc oxidé silicifère*, Haüy; *zink-glas*, Hausmann; *Galmei*, Haidinger.—Two varieties of this mineral exist;

the one anhydrous and the other hydrated. Anhydrous oxide of zinc is found crystallized in regular hexahedral prisms of a green or grey color; translucent, sometimes transparent, with a vitreous lustre on the surfaces of the fracture, which is somewhat conchoidal and uneven. Its streak is white. Before the blowpipe it is infusible, and is only reduced when mixed with charcoal, and submitted to a very high temperature; heated with soda on charcoal, it affords a sublimate of oxide of zinc; with a solution of nitrate of cobalt it affords the characteristic green color of zinc; it is decomposed by mineral acids, yielding a jelly of silicic acid. It is composed of—

Oxide of zinc,.....	71.32
Oxide of lead,.....	2.66
Oxide of iron,.....	0.67
Silicic acid,.....	25.35

100.00

HYDRATED SILICATE OF ZINC—*Electric calamine.*

—Silicates of zinc, especially this variety, were long confounded with calamine or carbonate of zinc, notwithstanding the great difference which exists between the two minerals. Electric calamine occurs in stalactitic, mammillated, botroidal, and massive forms, as well as in crystals of the right rhombic system. Its usual color is white, but in this respect it varies to shades of yellow, brown, green; its lustre is vitreous, and its streak white; it is phosphorescent when rubbed, and becomes electric by heat; its streak is white; it has an uneven fracture, and a specific gravity of 3.3 to 3.6. When heated on the matrass it yields water and turns white. It swells on charcoal before the blowpipe, and shines with a green light, but does not fuse, excepting a little on the edges; in other respects it comports itself like the anhydrous compound. The pure silicate is composed of—

Oxide of zinc,.....	67.07
Silicic acid,.....	25.48
Water,.....	7.45

100.00

corresponding to the formula $\text{ZnO}, 2 \text{SiO}_2, \text{HO}$. In most cases, however, this mineral is associated with various extraneous matters, as shown in the annexed analyses—

	Berzelius. 1	Berthier. 2	Smithson. 3	Thomson. 4
Oxide of zinc,.....	66.84	66.0	64.5	68.3
Silica,.....	24.89	25.0	25.5	25.0
Oxides of lead and tin,.....	0.28	—	—	—
Water,.....	74.45	9.0	10.0	4.4
Carbonic acid,.....	0.54	—	—	—
Loss,.....	—	—	3.3	—
	100.00	100.0	100.0	100.8

	Lowé.		Arfvedson.	Henry.	Berthier.	Locanna.	Kersten.	Jackson.		Berthier.	Selsson.
	1	2	3	4	5	6	7	8	9	10	11
Zinc,.....	61.40	62.62	66.34	66.46	63.0	55.0	64.22	63.62	52.0	64.5	53.17
Iron,.....	1.29	2.20	—	—	3.4	8.6	1.32	3.10	10.0	4.0	11.79
Cadmium,.....	1.50	1.78	—	trace	—	—	trace	0.60	3.2	—	—
Antimony, lead, and oxygen,....	—	—	—	—	—	—	0.72	—	—	—	—
Manganese,.....	—	—	—	—	—	—	—	—	1.3	—	0.74
Sulphur,.....	33.15	32.72	33.66	32.22	33.6	36.2	32.10	33.22	32.6	33.0	35.73
Water,.....	—	—	—	—	—	—	0.80	(earthy matters 1.5)		—	—
Loss,.....	2.66	0.68	—	1.32	—	0.2	0.84	—	0.9	—	—
	100.00	100.00	100.00	100.00	100.0	100.0	100.00	100.54	100.0	100.0	101.43

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7 G.

Numbers 1 and 2 in the foregoing table were from Limburg, 3 from Breigau, 4 from Rezbanya, and 5 from Leadhills.

This mineral is generally associated with calamine in veins containing iron and lead ores and blende; it is found in most of the localities already mentioned as containing calamine. Considerable quantities of it are mined at Bleyberg and Raibel in Carinthia; in Brissgau, Hungary; and at Tarnowitz in Silesia; it is also found in Poland, Gallizia, Baden, in the Tyrol, and in Banat; at Alcares in Spain; at Altenberg, near Aix-la-Chapelle; at Moresnet, near Liege; near Goslar in the Hartz; at Matlock, Derbyshire; in the Mendip Hills and Flintshire in England; at the Wanlock-head; and the Leadhills in Scotland, and several other localities.

SULPHIDE OF ZINC—*Blende; zinc sulfuré; sink-blende.*—Blende occurs in a variety of conditions—massive and crystallized in octa- and dodecahedrons and other allied forms, derived from the cubic system, its color varying between black, brown, red, yellow, and green. The crystallized variety is translucent, transparent, and opaque; it has an adamantine lustre, a conchoidal fracture, and a cleavage parallel to several of its faces; it gives a white, shading off to a reddish-brown, streak, according to its purity; it is brittle, and has a specific gravity of 4.0 to 4.1. By friction some varieties are rendered electric. Heated alone it decrepitates violently; it is infusible, excepting slightly on the edges in the blowpipe flame; but it gives, under a strong oxidizing flame, a sublimated areola of oxide of zinc round the assay; with carbonate of soda on charcoal it is reduced. When treated with nitric acid the base is dissolved, and the sulphur left in proportion to the strength of the acid employed. When pure, sulphide of zinc consists of equivalent proportions of its constituents, corresponding to the formula ZnS , and is composed centesimally of—

Zinc,.....	67.03
Sulphur,.....	32.97

100.00

Generally, it contains several impurities, such as sulphides of iron, of lead, of cadmium, and of antimony; the first of these is more frequently met with in the dark, and the second in the reddish striated kind. The following are analyses of a few samples of blende from different localities; namely, those marked 1, 2, and 3, from Przibram; 4, a transparent variety from New Jersey; 5, from Bagnères de Luchon; 6, from Chérones, in the department of Charente; 7, from Raibel in Carinthia; 8, from Eaton; 9, from Shelburne in New Hampshire; 10, from England; and 11, from Christiania:—

Blende is found, as before stated, in the metalliferous mountain and magnesian limestone, especially in England, in veins and beds associated with lead, iron, and copper ores. In Cornwall its presence is observed in the older transition rocks, and chiefly accompanying copper pyrites. The variety so found, from the large quantity of sulphide of iron, is mostly of a black color—hence the miners term this mineral *black jack*. The ore is found in more or less abundance in Hungary, Transylvania, Bohemia, Carinthia, and the Hartz; large quantities of it are obtained in Cumberland, Derbyshire, and Cornwall, in England; Flintshire, in Wales; in Perthshire, the Leadhills, and the coal fields round Edinburgh and Lanarkshire, in Scotland.

SULPHATE OF ZINC.—*Goslarite, sinkvitriol, white vitriol, aluminat of zinc, gahnite spinelle, zincifere*, and a few other minerals of zinc exist; but their importance in relation to their abundance, or for their application in the metallurgy of zinc, is not so great as to require a description here.

PREPARATION OF ZINC.—To obtain perfectly pure zinc is a task of some difficulty, so much so that the commercial article is never met with in a pure state, but rather with variable quantities of arsenic, cadmium, tin, lead, manganese, iron, cobalt, and nickel. In order to obtain perfectly pure metal, the purest commercial zinc should be dissolved in dilute sulphuric acid, filtered from any residue, and the foreign metals thrown down by immersing plates of zinc in the liquid till no further deposit takes place. After separating the precipitated metals, which may be tin, lead, copper, cadmium, antimony, and a trace of arsenic, the solution is treated with carbonate of soda, and the carbonate of zinc, which falls after filtration and thorough washing, is dried, heated to redness to expel carbonic acid, mixed with charcoal or lampblack, and introduced into a crucible as represented in Fig. 623, placed in a furnace,

Fig. 623.



and the metal reduced and recovered by the method known as distillation *per descensum*. In this figure, the crucible wherein the mixture of carbonate and charcoal is placed, is shown by A; it rests upon a disc of clay, B, which, together with the bottom of the crucible, is perforated for the purpose of passing a clay tube through both, one end of which opens at the top of the crucible near the cover, and the other dips into a cup of water, C, placed beneath the grate and ash-pit. The crucible being fixed, with its charge and its cover closely luted with clay, is placed in the furnace and heated to whiteness, when the reduced particles of the metal pass off in vapor, which finds an outlet in the lower opening of the tube, and condenses in the cup of water in grains. The zinc obtained in this way will be very pure, but to obtain it in absolute purity, it is necessary to have recourse to electrolysis from a solution of zinc which has undergone the above-

mentioned purifying operation, and from which the iron, manganese, and other bodies which may be deposited on the electrode, are separated by treatment with an excess of caustic potassa, subsequent precipitation of the zinc as carbonate, washing, and re-solution. The distillation of zinc being always conducted at a white heat, a repetition of the distillation, however often repeated, is not sufficient to separate many impurities of a metallic nature, which greatly injure its properties, and prevent its applications in many operations of a chemical and manufacturing nature. The substances with which it is most liable to be contaminated when prepared in this way, are lead, tin, antimony, cadmium, and arsenic, as these metals evaporate with the zinc and alloy themselves with it. A simple process adopted to free zinc from several of the preceding metals consists in incorporating some sulphur alone or mixed with grease in the melted metal, and stirring the whole rapidly with a wooden slip. The foreign metals are by this operation converted into sulphides, but traces of them are still retained in the melted zinc. Another method is to granulate the zinc by melting it in a crucible, and pouring it while fluid into a tub of water, then mixing the powder with a quarter of its weight of nitre, and introducing the mixture into a crucible, taking care that a portion of the salt rests beneath and upon the metal. The crucible is then heated in a furnace till vivid combustion ensues, after which it is taken from the fire, the slag removed from the surface, and the melted metal poured into water. Arsenic and iron are thus removed.

PROPERTIES OF ZINC.—When pure, this metal has a bluish white color, somewhat similar to lead or aluminium, and a strong metallic lustre. It crystallizes in long regular hexagonal prisms, according to NAGGERATH, but others give the crystalline form as cubic prisms. NICKLES asserts that zinc distilled in an atmosphere of hydrogen forms well-defined pentagonal dodecahedrons on cooling. When freshly fractured, its crystalline texture is lamellar, the plates sometimes appearing of considerable size. At ordinary temperatures it is brittle, of a moderate hardness, and difficult to file, but when heated between 212° and 300° it acquires a considerable degree of malleability, so that it can be drawn into wire or rolled into thin bands and sheets. Mr. FORD of Coalbrook Dale, who, according to GRAY, was the first person in England who employed the metal in casting fire-engine cylinders, states that, by the mere warmth of the hand, the strips of metal which were as brittle as glass at the ordinary temperature, could be wound round the finger like slips of paper. If the heat be raised to 400° or 410° its ductility is destroyed, and it becomes so brittle as to be reduced to powder in a mortar by ordinary grinding processes. Zinc emits a peculiar odor when rubbed. Its density, according to the mean of several experiments of BRISSON, KARSTEN, PLAYFAIR, and JOULE, is 6.89; the melted metal after cooling gave JOULE only 6.54. It fuses at 705° according to GUYTON MORVEAU, but DANIELL gives the fusing point 774°; at white heat it boils, emitting vapors which burn in the air or in oxygen gas with a very brilliant white light, producing oxide of zinc, which

condenses in filamentous flocks on a cold surface held over the flame, or on the walls of the crucible in which the combustion is effected; this is the *philosophical wool*, the *flowers of zinc*, or *pompholyx* of the old chemists. At a red heat zinc decomposes water, setting free the hydrogen of the vapor; the same effect is produced at ordinary temperatures under the influence of weak acids, and with considerably greater energy than by heat alone. In the latter behavior a remarkable difference is manifested when pure and commercial zinc are submitted to the action of the same acid, the former dissolving so slowly that it requires the action to be continued for a period of eight days to produce the same effect as that which is effected upon the latter in a space of one hour. This behavior was made the subject of a careful investigation by DE LA RIVE, who found that the action of the acid is increased by the presence of certain proportions of many metals. By alloying nine parts of pure zinc with one part of the several metals mentioned below, and employing dilute sulphuric acid, he found that the effect of the acid, measured by the volume of hydrogen disengaged in equal times, stood in the relation of the annexed numbers:—

	Gns. disengaged.
Commercial zinc and alloys of zinc and iron, ..	100
Alloy of zinc and copper,	43
Alloy of zinc and lead,	15
Alloy of zinc and tin,	12
Distilled zinc,	5

One twentieth of the quantity of iron alloyed with zinc is sufficient to produce an effect equal to that of commercial zinc, and even a spiral of platinum round a bar of zinc was found to increase the action of the acid considerably. On the other hand, he observed that the acid which effected the most rapid solution of the metal, was a mixture of thirty-three parts of sulphuric acid and one hundred of water. The consideration that the zinc, on being alloyed with any metal, constitutes a kind of battery within itself, and the knowledge that the above acid is the one which possesses the greatest power of conducting electricity, led M. DE LA RIVE to the conclusion that the greater or less energy with which a plate or bar of zinc decomposes water, is dependent upon the galvanic effect of the metals associated with the zinc and of the acid body employed.

Zinc abstracts oxygen from a great number of acids containing this element. Boiling solutions of potassa and soda likewise oxidize it with disengagement of hydrogen, the oxide of zinc formed dissolving in the alkali, and forming probably the radical of an alkaline salt. Exposure to dry air, however long continued, is insufficient to tarnish bright metallic zinc; but when moisture is present it readily undergoes oxidation, a whitish coating forming upon it; this, however, retards to a great degree its further corrosion by atmospheric influences, so that it resists exposure very well; and hence, its very extended use in roofing and other applications where iron would soon become oxidized and worn away. Zinc forms an extended class of salts with acids, many of which are of some importance in many departments of art and manufactures as well as in medicine, and the metal itself has of late years been applied to a great many important uses. Zinc has the

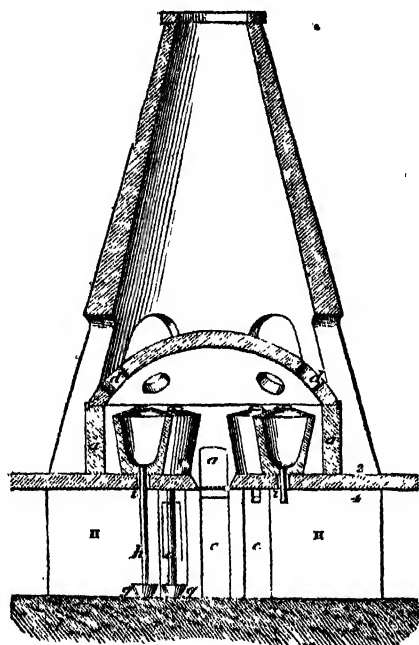
atomic or combining number 32; and its symbol, or chemical formula, is Zn.

METALLURGY OF ZINC.—The principal places for the production and manufacture of zinc are, in England, Swansea, Carlisle, Bristol, Birmingham, and the neighborhood of Sheffield; Flintshire in Wales; Upper Silesia in Germany; and Vieille Montagne in Belgium. The latter establishment has considerably increased during the last twelve years, but it has not attained the magnitude of the Silesian works, which are the largest of the kind in the world.

ENGLISH PROCESS.—The ores which are principally employed at Bristol and Birmingham, are those from the Mendip Hills and from Flintshire, while the Sheffield furnaces derive their stock from Alston Moor in Cumberland, and from Derbyshire. A large quantity of blende is likewise obtained from Cornwall, which is submitted to a preparatory roasting. The ore is sorted, and any blende which may be mixed with it is separated from the calamine; the latter is sometimes ground under head rollers, and roasted in a reverberatory furnace, to expel all its moisture and carbonic acid. This preparatory roasting is not universally practised, however, as some smelters merely break it up into fragments about the size of a pigeon's egg, and in this state mix it with its bulk of coal or slack, and submit it to the reduction process. Blende is always roasted before reducing it to metal, for which purpose it is sorted and broken up into small pieces of about half a cubic inch, and introduced into a reverberatory furnace, where it is roasted during ten to twelve hours without intermission. The furnace is ten feet long, eight feet wide, a half foot between the bed and the roof in the middle, and one foot and a half at the bridge. A continual rabbling is given to the ore, which is spread on the bed to the depth of four or five inches. During the period of the roasting, the ore suffers a loss of twenty per cent. from the sulphur expelled. Four tons of coal are said to be consumed during each operation. The charge for reduction is then compounded of one part of calcined blende, one part of roasted calamine, and two parts of charcoal. In the English system, the furnaces shown in the annexed figures are employed; their peculiar feature is their being adapted to the practice of the system of distillation *per descensum*. They consist, as shown in Fig. 624, of an inner cupola, A A, enclosing a double row of crucibles, G G, the whole enclosed by a novel or conical brickwork chimney, D, similar to that of a glass furnace or pottery kiln. A number of openings, B B, are constructed in the cupola corresponding to the number of pots in the furnace, and which serves to charge and secure the pots in their places when necessary. For the convenience of the workmen the outer cone has doors, C C, before each pot. A fire, F, runs across the centre of the hearth and heats the row of four pots on either side, the smoke and gases passing off by the apertures, B B, and outwards at the mouth of the cone, D. The ash from the grate falls into the pit, E, at either side of which, and beneath the pots, is a gallery, H, where a number of dishes or other vessels are placed for collecting the zinc, conducted to them by iron pipes, having one end inserted into the aperture in the bottom of the pot, while the other

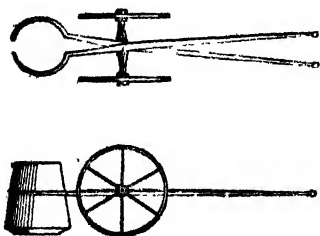
drops into the dish already mentioned. To charge the furnace, the crucibles, which are previously heated to redness in a reverberatory furnace, are carried by a pair of large iron pincers, slung in chains, and supported on a kind of over-head railway—Figs. 624, 625—much in the same way as glass-pots are inserted

Fig. 624.



and withdrawn from the furnace. They are then introduced by means of an aperture in the side of the dome, and placed in their position beneath the apertures in the top, so as to rest on each side of the wall

Fig. 625



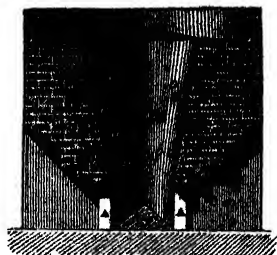
of the furrow opening into the chamber, H. The charge for each pot or crucible is composed of equal bulks of ore and slack when calamine either crude or roasted is used, or if a mixture of calcined blende and calamine be employed; these, in the proportions already stated, are introduced through the apertures in the dome, the outlet in the bottom of the pot being secured by a plug of wood. The fire is then urged till the contents of the pots are brought to a full red heat, approaching to whiteness, and when the vapors arising from the ore are observed to burn

with a white light, the covers are placed upon the several pots and well luted, the pipes are likewise inserted in the bottom, and the distillation is allowed to proceed, the temperature being always maintained at a high white heat. To prevent the materials in the pot from falling through, the end of the pipe is plugged with wood, but as it becomes charred, it offers sufficient space for the metal, in its passage downwards, to percolate through it without allowing any grosser matters to descend. Any metal condensed in the pipes is removed by introducing, from time to time, a small iron rod or wire, which clears it away; if this operation be neglected, the outlets are apt to get clogged up, and the tension of the enclosed gases will endanger the explosion of the covers. Usually the period occupied in a single distillation is about six days, or five distillations in fourteen days, in which from ten to ten tons of ore are worked off, with a consumption of twenty to twenty-five tons of coal. The metal obtained amounts to thirty-five or forty per cent. of the calcined ore employed. When no more metal is condensed, the refuse matter in the pots is discharged by removing the pipe in the bottom and the cover, and then raking it out through the bottom aperture; after this operation the latter is plugged, to prepare the retort for receiving another charge. Each pot serves to distil about forty charges before it gets broken; when this happens, the fragments are withdrawn through an opening made in the surrounding brickwork, and the place of the broken pot is supplied by another annealed at a red heat in a reverberatory, as mentioned above. The collected product of the distillation, which is chiefly in drops and fine metallic powder mixed with some oxide of zinc, is melted in a large iron pot set in brickwork, and heated by a fire beneath it, when the lighter oxide and other impurities form a scum on the surface of the bath of melted metal; the former is skimmed off, and the latter cast into bars or cakes, in which state it is sent to market.

PROCESS PRACTISED AT VILLE MONTAGNE.—The mineral wrought at this establishment is a mixture of calamine and oxide of zinc, which is of a compact and crystalline nature, intermixed with 30 per cent. of clay in amorphous masses. As a preparatory operation, the mineral substance, as taken from the mine, is exposed to the air for the purpose of allowing the gangue to disintegrate, with the view of rendering its separation more easy and complete in the preparatory process to which it is submitted. There are two varieties of the carbonate treated, one of a reddish color, containing a considerable amount of iron; the other white and more compact. The ore is placed in heaps, and turned over from time to time to permit the air to pass through it more freely. After a period, varying from three to twelve months, the heap is picked, and the fragments of pure ore of the size of pigeons' eggs are selected from the rest. The refuse matter is then screened, and the coarser portions again picked out by hand; finally, the reduced fragments are washed upon the inclined plane, and the chief part of the clay is thus removed. There is a considerable difference between the periods required to disintegrate the two varieties of the mineral: by a

three months' exposure the red kind is sufficiently decomposed to part with the most of its impurities, whereas the white variety takes from nine to twelve months to effect the same change; in the former the loss averages fifteen per cent., whilst in the latter it often amounts to fifty. The selected ore is then calcined, sometimes in a reverberatory, but more frequently in a conical kiln, somewhat similar in form to that in which lime is burned, and which has the advantage of being continuous in its operation. Fig. 626 represents this kiln: it is heated by two lateral fires inclosed within an arch, the products of combus-

Fig. 626.



tion from which are draughted into the interior from a channel or flue by twenty different apertures, *o, o, o*, at various points of elevation. The bottom of the kiln inclines towards the drawing doors, *A, A*, owing to the two cast-iron plates of which it is composed, *f, f*, being laid together at an angle of 45° , and hence the descending body of calcined ore falls in almost equal portions towards each of the rectangular outlets already mentioned. Coal is preferred for heating in this case, owing to the high temperature necessary to calcine the mass of ore which is introduced at regular intervals at the top. After drawing out the roasted ore it is ground under headstones, and sifted, so that its fineness is insured; it is then mixed with its proper quantity of combustible matter, which may be charcoal or fine coal, and introduced into the retorts for smelting. These retorts consist of cylinders of refractory clay, closed at the end which is inserted into the furnace, and open at that one which protrudes; to this end is adapted another cylinder of sheet-iron of a conical form, for the purpose of condensing the metallic vapor, and this in turn has a third pipe of the same form, but much smaller, appended to it. These several parts are seen in Fig. 627, *A* being the retort, *B* the condenser, and *C* the outer cone;

Fig. 627.



the first is three feet eight inches in length, and six inches in diameter, the second is sixteen inches in length, and the third about the same, only that both taper, so that the aperture of the apex of *C* is not greater than three-fourths to one inch in diameter. These are placed in a peculiar kind of furnace represented in elevated section in Figs. 628 and 629, the

latter in the line *A B* of the former. The stack consists of four distinct furnaces, each in the form of a semi-cylindrical chamber, eight feet eight inches from the highest point of the arched roof to the floor, the back of the chamber being constructed so as to recede slightly from the bottom or floor upwards, as shown by *b d*, in Fig. 629, and the front, *a c*, being left open for the convenience of introducing the retorts. The fire which heats the chamber and its complement of retorts is shown at *F*, and is placed beneath the level of the floor of the smelting house, the combustible gases and other products passing upwards through four apertures in the grate, shown at *e, e, e*, and thence by a double flue, *g, g*, finding an exit overhead into the chimney, *C*. The latter forms one massive construction, embracing the four outlets, each closed by a damper. In each of the chamber furnaces forty-two retorts, *g, g*, are heated; these being placed in rows one above the other, as shown in the drawing, the posterior end resting upon a ledge made for the purpose in the masonry or brickwork. In the front the distillatory cylinders are supported by plates of cast-iron, so fixed at each side of the face of the furnace as to allow the cylinders to slope downwards from the back to the front. Before placing the retorts in this furnace, a brisk fire is maintained in it for some time, so as to bring the interior to a bright red or white heat, the face of the furnace being built up with bricks or fragments of broken retorts. When this condition has been attained, the cylinders, which should be previously heated to redness in a reverberatory, are fixed in their places one by one, the interstices between each retort at the front being closed up with fire-clay. At first, a small quantity of the mixture of ore and coal is submitted to reduction in the cylinders, the condensing cone and adapter attached and luted, and any metal given out collected in the manner presently to be indicated. These preliminary charges are successively increased for a period of three or four days, or until the furnace is found to be in a proper working condition. At this period the charge attains its mean, and consists of one thousand one hundred pounds of the roasted, ground, and sifted calamine, intimately mixed with five hundred and fifty pounds of bituminous coal in fine powder, for the forty-two retorts. This is introduced into the clay cylinders by means of a long half-cylindrical shovel attached to a long iron handle, commencing with the lower retorts, and proceeding to the higher ones in succession. When all are filled, the flue, which is usually stopped by having the damper down, is

opened, and an increased firing resorted to.

As the contents of the retorts attain a strong red heat approaching to whiteness, they evolve a considerable amount of carbonic oxide, which burns at the mouth of the cylinders with a bluish flame; after a while the appearance of the flame becomes more brilliant, and of a greenish white, showing that portions of the zinc vapor have been volatilized. As soon as this symptom is observed, the iron condensing tubes are attached to the open end of the retorts, the joining is well luted with refractory clay, and finally the adapters being fixed upon the condensers and luted likewise, the distillation and recovery

of the zinc are proceeded with. Every attention is now given to equalize the heat in the interior of the furnace, in order that the upper retorts may be worked off equally well with the lower ones; but this result can

seldom be exactly attained, and to compensate for this defect the more easily reducible ores are charged into the upper retorts, and the more refractory into the lower ones, where the heat is greatest. At intervals

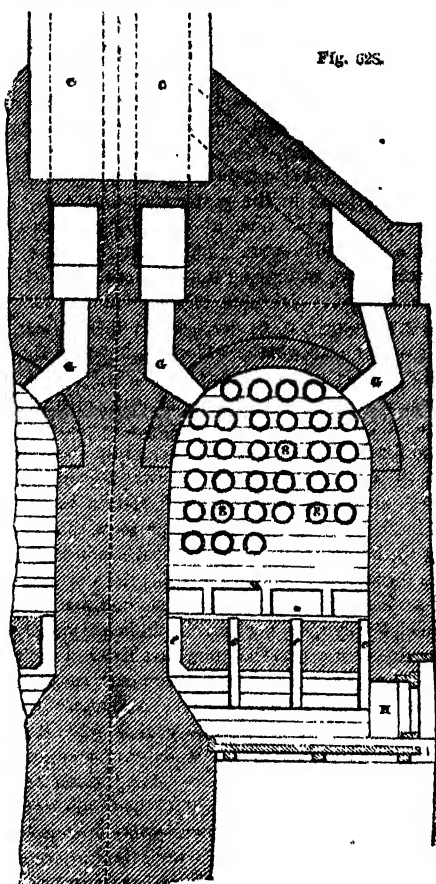


Fig. 625.

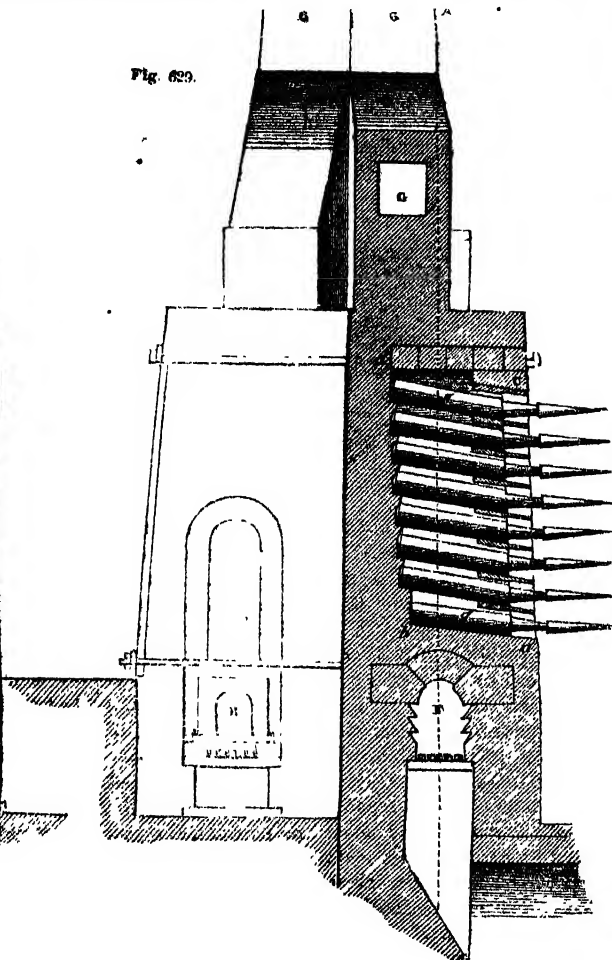


Fig. 629.

of two hours after the distillation commences, the outer adapter is removed by means of tongs, and the oxide of zinc, or *cadmia*, collected in it is removed, to be again submitted to the retorts in a succeeding charge. An assistant then holds a large iron ladle, called a *poëlon*, under the mouth of the condenser pipe, and the smelter rakes out the fluid zinc at the bottom of it, as well as the drops of metal attached to the sides and other parts. After carefully separating the oxide of zinc which covers the metal thus abstracted, the latter is cast into ingots, weighing from seventy-five to eighty-five pounds. The adapters are then replaced and secured as before, and after two hours the zinc produced is again removed in the manner stated.

A charge of ore commenced at six in the morning, and worked in this way, is found to be exhausted of its reducible metal at five in the afternoon, so that two charges are worked in the twenty-four hours. When one operation is finished, the adapters, con-

densers, and retorts are thoroughly cleansed and scraped out before the next charge is introduced; and the oxide resulting from every operation and collected from the adapters and skimmings, is worked up as part of the ore of the preceding charge. The argillaceous residue cleared out of the retorts after the distillation has ended, is found to contain as much as ten per cent. of zinc; but being in the form of silicate of oxide, it resists the action of the charcoal and remains intact. About thirty per cent. of the calamine submitted to reduction is obtained in the form of metal. The distilling campaign lasts two months, during which time the fires are maintained at their greatest activity consistent with the work to be accomplished. At the end of this period, the necessity for repairs and replacing old retorts compels a cessation of the smelting for the time required to effect the necessary renovation.

Process for the Smelting of Zinc Ores in Upper Silesia.—The ores of zinc worked in this district

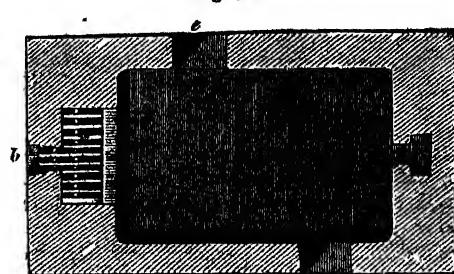
are principally a carbonate mixed with some oxide, having a calcareous and argillaceous gangue; and as

Fig. 630.



the latter ingredients would materially impede the reduction of the principal compound, the oxide of zinc,

Fig. 631.



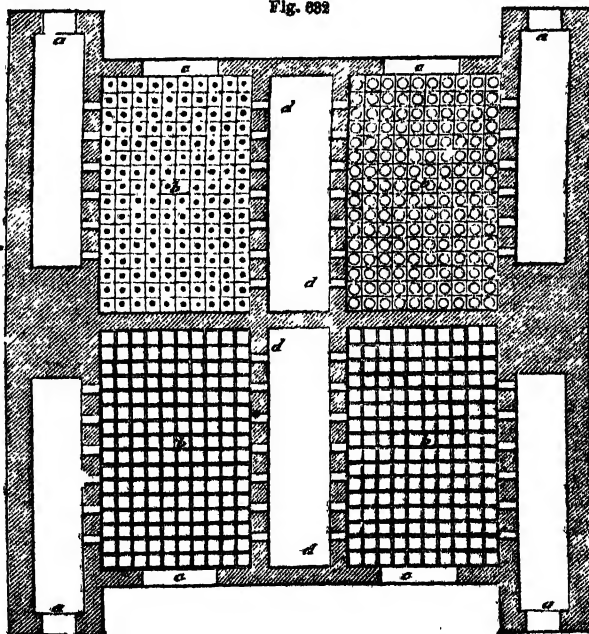
they are as far as possible removed by processes of disintegration and washing analogous to those already mentioned in connection with the Belgian method.

As in the English and last mentioned smelting establishments, the purified calamine is here submitted to a preparatory calcination for the purpose of expelling the water and carbonic acid. The furnace used for this purpose is shown in Figs. 630 and 631. It consists of an ordinary reverberatory, of which *a* is the fire-grate, *b* the doors by which the fuel is introduced, *c* the fire-bridge, *d* the interior of the furnace, the bed of which is constructed of ordinary bricks, *e e* the working doors by which the charge is rabbled and worked during the calcination, *f* the flue leading to the chimney, and *g* the superior aperture whereby the ore is charged upon the bed of the furnace. The latter is lighted in the usual way, and as soon as the interior attains a strong red heat, from thirty to thirty-five hundredweight of ore are introduced at *g*, the workmen spreading it out upon the sole with rakes at the working doors; this done all the openings are closed, and the roasting is allowed to proceed uninterruptedly, with the exception of an hourly rabbling for the purpose of exposing a fresh surface of ore to the flame, till the whole of the moisture and carbonic acid is expelled. The completion of the work is judged of by the apparent heat of the interior of the

furnace, the facility with which the ore falls to powder, and its change of color, which in case of the red calamine being operated upon should be brownish, and of the white calamine brownish-red. When these appearances are observed the charge is drawn, and a second, which had been placed on the platform in the interval between the charging and drawing of the roasted ore, introduced in its stead, the largest fragments from the last operation being ground and added to the fresh ore to be recalcined. Four charges are thus treated in the twenty-four hours, making a total of nearly six and a half tons of ore, which yield about seventy-two hundredweight of calcined calamine, with a consumption on an average of twenty-three bushels of fuel.

The Carinthian Process.—Here the furnaces are worked on the same principle as the English ones, but the details are different:—Figs. 632 and 633 show a plan and sectional elevation of the Carinthian furnace. As at the *Vielles Montagnes* smelting works, four furnaces are connected in one block with one chimney; they consist of rectangular chambers arched over at the top, *b b b b*, heated by fires, *a a a*, from which the heated gases, and flame enter by openings, *a' a'*, to the space occupied by the retorts. Above the sole of the retort chamber, *b*, is placed a trellace work of iron, in the squares of which the vertical retorts, *p p*, are fixed by means of a clay conductor, *a*, which receives the zinc separated in the vertical cylinder. *c c c c* are the side doors affording ingress for placing the conductors and retorts in position for operations, *et cetera*; *d d*, outlets for the waste gases from the furnace into the flues, *e e e e*, leading to the chimney, *h*. Beneath the conductors, *n n*, is placed a flooring of plate-iron, *r r*,

Fig. 632.



resting on cross supports, as well for receiving the zinc which falls in the course of the distillation as for excluding the atmosphere, and thereby preventing

the reoxidation of the metal. Each of the distilling compartments admits of erecting one hundred and sixty-four vertical retorts with their conductors, but the four ranges more distant from the heat contain only

Fig. 633.

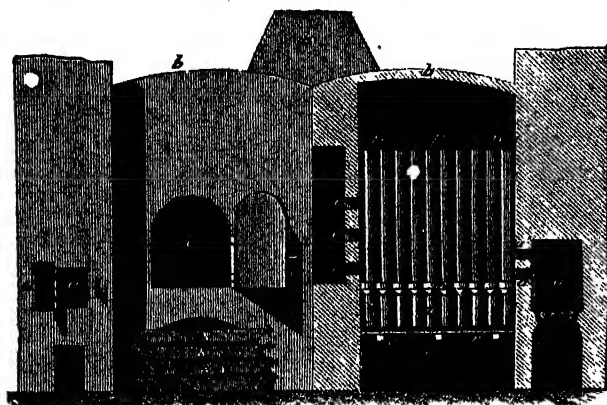


Fig. 634.

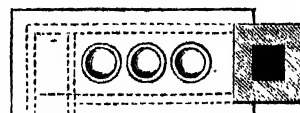
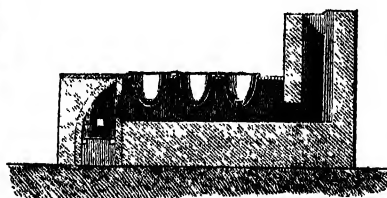


Fig. 635.



empty cylinders in process of being baked by the waste heat; and even for those within the range of a distilling temperature a different mixture is made for the charging according as the cylinders are nearer to or more distant from the fire. This mixture has the following composition:—

	For the four ranges nearest the fire.	For the other two ranges.
Roasted calamine,	1820 lbs.	520 lbs.
Wood charcoal, ground,	504 lbs.	224 lbs.
Common salt,	36 lbs.	16 lbs.
Water charged with 1-200ths of potassa,	280 lbs.	70 lbs.

The four first ranges contain sixty-four cylinders, whereas the following two contain but twenty; the remaining spaces being left free for the passage of the products of combustion. Two adjoining furnaces are always worked together, and in these one hundred and sixty-eight cones are in operation. During the course of the distillation, which occupies thirty to thirty-six hours, the consumption of wood as fuel amounts to seven hundred and fifty cubic feet, and the proceeds average eight hundred pounds of metallic zinc.

Considerable loss of time, fuel, and retorts is incurred from the intermittent nature of the process. After collecting the metal which falls upon the plate-iron flooring, indicated by *rr*, in the foregoing figures, it is refined from oxide and other grosser impurities by fusion in pots placed in a furnace, represented in plan and section in Figs. 634 and 635. After melting the metal in the series of pots shown in these furnaces, the scum of oxide, carbonaceous matters, *et cetera*, rises to the surface, and is removed by the ladle, and the purified metal is cast into moulds for the market.

Silesian Method.—In Upper Silesia the reduction of zinc ores is carried on by a distilling process in a muffled furnace, as will be described presently. The principal seat of the smelting is in Silesia, where, in 1848, there were no fewer than thirty-five establishments for the distillation of the metal. In the Rhine Province, at the same period, there were five, and in Westphalia one. With the growing demand for zinc, however, these establishments have, during the last ten years, been enlarged and rendered more effective, so that

Fig. 636.

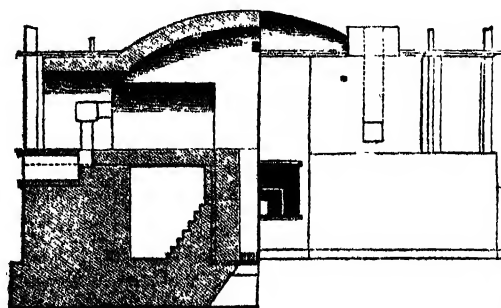
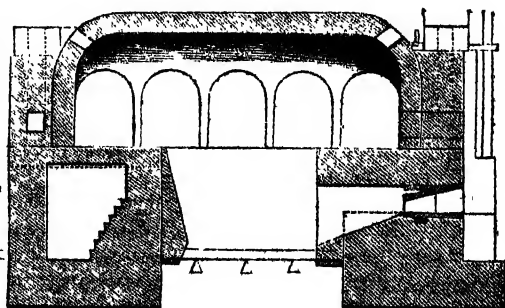


Fig. 637.



their capacity for working is greatly increased. It may be remarked that the *material* of the muffles consists of fire-clay, obtained from Ruda Krzeszowitz and Kattowitz in Upper Silesia, as also from Murau

in Poland, and which, after the necessary preparation, is mixed with reduced broken muffles, the whole being properly blended together to give the articles the necessary cohesion and compactness. The proportion of clay and potsherds is invariably two of the former to one part of the latter. These muffles are always made by hand, and submitted to a gradual course of

deglazation, then annealed at first at a very moderate temperature, and finally at a full red heat in a furnace especially constructed for the purpose, somewhat in the manner of making glass-pots.

Figs. 636, 637, 638, 639, 640, represent the ordinary furnaces, called *double ovens*, adopted in Upper Silesia for the reduction and distillation of zinc from its ores.

Fig. 638.

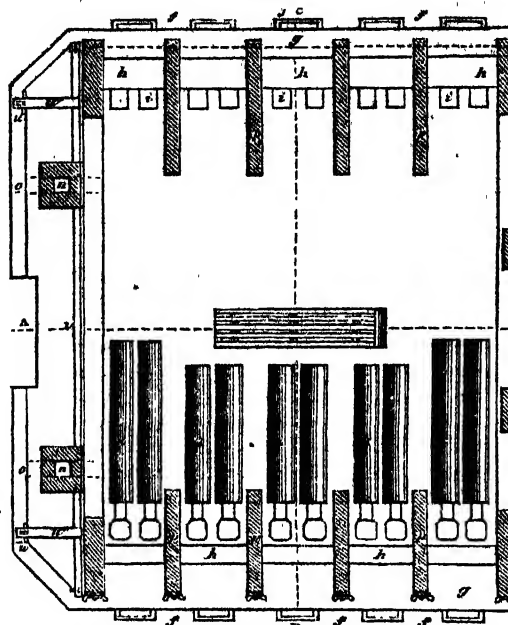
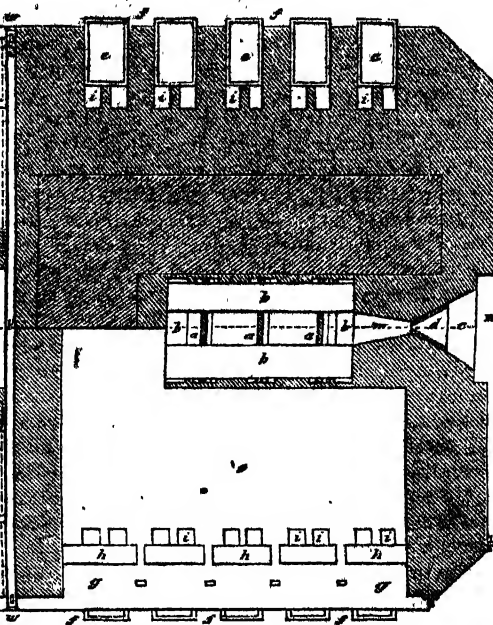


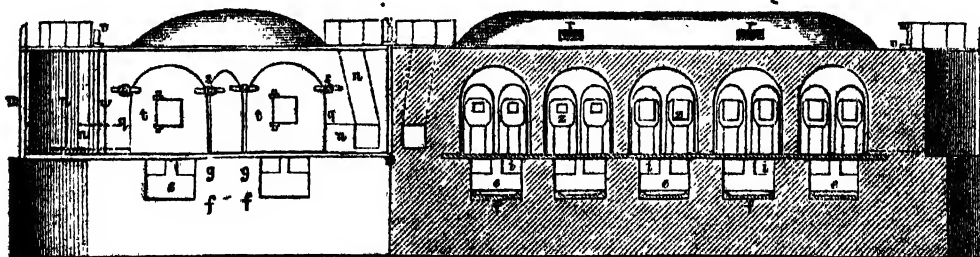
Fig. 639.



They have ten primary large chambers; but these in working are divided into twenty smaller parts, the large muffles being so constructed that the back wall is common to the two ranges. Fig. 636, is a section representing a longitudinal view to the left hand, following the line A B, and to the right the line C D in Fig. 637. Fig. 638 shows a ground plan at *a' b' c' d'* in Fig. 636, and *d'' d'''* in Fig. 637, in the upper half of the left side, and in the under half at *a' b' c' e'* in Fig. 636, and *e'' e'''* in Fig. 637. The portion to the right

exhibits the furnace vertically under the dome. The same letters indicate like objects in the several figures. Three triangular cast-iron bars, *a a a*, secured at each end in the walls of the furnace, bear four iron plates, *b b*, laid transversely, to form the fire grate; the whole constituting a rose over the air channel and ash-pit. The fire-door, *c*, which is lined near the grate with a cast-iron box, *d*, is closed with a door of plate-iron, the sole of the aperture being likewise secured by a similar plate; *e e*, *et cetera*, are inclosed troughs, into

Fig. 640.



which the distilled zinc trickles from the apertures of the retorts. The base of these is of iron plates, *f f*, to which deep iron bands are fixed for preventing the overflowing of the metal as it falls from the mouths of the retorts opening into them. All these receivers are closed by a single plate, *g g*, extending the whole

length of the oven, and called the *hearth-plate*. They are but one foot wide, and protect, therefore, only the front part of the receivers; the interior of the latter being secured by supplementary closely fitting plates, *h h*, touching the hind part of the openings, *i i*, and towards which is the connection between the dropping aper-

tures and receivers. These hearth-plates, in order that they may not be warped by the heat, are fastened by three cast-iron fluted anchors of the form of the letter Z. The walls, *l*, of the fire-chamber are constructed of the best fire-bricks; the connection between the fire and fire-door being an inclined canal, *m*. The upper rim of the fire-chamber is a few inches higher than the receiving troughs, so that the hearth slightly inclines from the middle to the side walls of the oven. The space between the posterior walls of the two adjoining ovens is filled with sand and rubbish; *n n* are side draughts for heating the rim muffles, and *o o* horizontal entrances for cleaning the same, which, however, are closed during the firing; *p p p*, *et cetera*, are pillars from three to five inches in thickness, constructed of clay, and furnished exteriorly with iron plates, *q*, secured to the hearth-plates, *g g*. These pillars form the support of the arches of the muffles which receive the retorts, as also of the overspanning dome. They should be as low as possible, so that the distance from the apices of the interior arches and the hearth be not more than three feet. The dome of the oven is constructed of a composition consisting of one-third part clay and two-thirds sand; its thickness when dry is eight or nine inches; *r r* are six cap or draught holes, by opening or closing which the heat can be directed towards any of the retorts which should happen to be working unsatisfactorily; *s s* hinges or clamps for fastening the doors, *t t*; *u* long bracing bars or anchors; *v* oblique ones, and *w* upright anchors, all applied for the purpose of giving solidity to the oven.

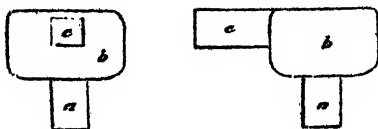
The retorts or muffles, *x x*, are set two and two within the muffle arches in the spaces between the pillars, *p p*, and placed as far back as possible, with their open faces to the front. When placed in their proper positions, the spaces between their walls and the pillars are blocked up with clay cement so as to confine the flame. The mouth of the retort is closed with a piece of clay called the bridge, *y*, and shown somewhat enlarged in Fig. 641. It has two openings; the under one, *a*, closed with a clay stopper during operations, for drawing out the residuary matter of the distillation, and the upper one, *b*, for receiving the neck of the conduit by which the vapors of zinc pass to the receivers. The latter part of the apparatus is seen in Fig. 642; the under part, *a*, is a clay pipe; the upper part consists of the head, *b*, and the neck, *c*. An opening in the head of this receiver serves for introduc-



Fig. 641. open faces to the front. When placed in their proper positions, the spaces between their walls and the pillars are blocked up with clay cement so as to confine the flame. The mouth of the retort is closed with a piece of clay called the bridge, *y*, and shown somewhat enlarged in Fig. 641. It has two openings; the under one, *a*, closed with a clay stopper

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Fig. 642.

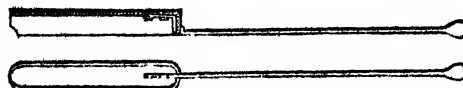


ing the small charging shovel—Fig. 643—to spread the charge within the retort. It is closed like the opening, *a*, in Fig. 642, during the distillation.

Before the muffles are placed in the distillatory oven, they are subjected to a strong red heat in the furnace

employed for annealing them. They are then placed two and two in the arched chambers of the zinc oven, and charged with a mixture of sixty-six pounds of

Fig. 643.



roasted calamine and an equal volume of cinders or small coal—forming about five per cent. of the weight of the ore—together with a few pounds of oxide of zinc and abstrich or semioxydised skimmings from the collected zinc. All these are intimately mixed together before their introduction through the upper opening of the muffle bridge, the lower aperture meantime being secured with a plate and lute of clay. When charged, the neck and condenser are fixed in their places, and all apertures and cracks safely coated with luting. The iron doors in front are closed to retain the heat, and the firing proceeded with. Scarcely a quarter of an hour after the closing of the front doors of the muffles elapses when the metal begins to pass over; nevertheless the distillation is not in full activity till six to eight hours after commencing. As in the other distillatory processes already described so in this: the zinc, deprived of its oxygen by the coal in the body of the retort, passes off into the neck and head of the conduit in the form of vapor, and then condensing falls through the descending pipe into the plate-iron receivers. The combustion of a portion of the zinc cannot be avoided, as it is impossible to prevent the admission of some air into the receivers and conduits. It is owing to this, that a portion of white oxide is always found in the receivers, averaging from two to four per cent. of the metal obtained. At the close of twelve hours all the metal is extracted, and a second charge is introduced, without, however, clearing out the residue in the retort until at the end of the second operation, at which period a new bridge plate may be supplied if necessary, or any other repairs made. Care should be taken to change the muffles of both working sides of the oven every six hours after their setting in.

When the calamine contains much cadmium, it is found that the first portions of the distillate are very rich in this metal; and the oxide produced by the combustion of portions of the metal in the neck of the retort is likewise richer in oxide of cadmium, both effects being due to the volatility of the cadmium being greater than that of zinc. Six hundred pounds of roasted calamine are worked off by a furnace of ten large muffles in twenty-four hours, with charges for each retort averaging six pounds. The estimated consumption of coal per every hundred of zinc obtained is twenty-eight cubic feet; the loss of the metal is estimated at eight per cent., and of large muffles twenty-eight for every thousand pounds of zinc obtained. The average produce from the calamine operated on is about fifty per cent. in the form of metal and oxide. But as the ore varies in its content of oxide of zinc, so also does the yield. To purify the metal resulting from the first distillation, it is melted in iron

pots, and the scum of oxide and other impurities separated. This amounts to eight per cent. ; but as it contains about seventy per cent. of metal, and is submitted to a new reduction, a considerable amount of it is recovered.

At Kloster, where blende is worked, the apparatus and system of reduction are the same as that just described, with the exception of the roasting furnaces, in which the sulphide of zinc is converted into oxide. These are also the same as those that have been previously described, and consequently need not be further referred to.

PATENT PROCESSES.—The only patents connected with the manufacture of zinc which are of any importance, are those of TROUGHTON and GRAHAM; the former sealed in 1839, and the latter in 1845. Other patents have been secured, but the Editor deems it unnecessary to dwell upon them.

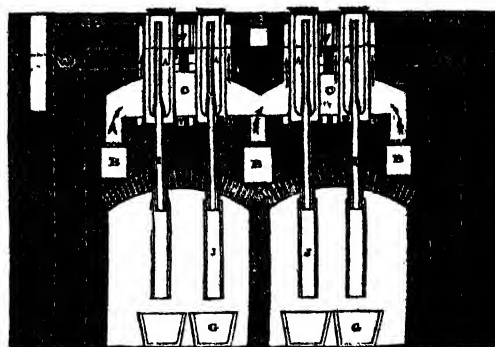
TROUGHTON's patent professed to deal with blende, and prescribes a form of furnace for the roasting, as also for the reduction. The first of these is in form like an ordinary reverberatory, with, however, three floors or hearths, on each of which the ore is spread, the heated gases and flame passing from the under chamber into the middle, and thence to the upper one, after which the gases proceed into the chimney. The connection between the several floors is made by apertures, covered by fire tiles during the roasting, but which are removed when it is necessary to transfer the ore through these openings from the upper to the lower ones. By apertures at the sides the contents of each floor are rabbled in the usual way. The charging of the ore is effected through hoppers at the top, and when roasted it is raked out into receptacles beneath the lowest hearth, by the workable openings already mentioned. A close fire, charged with fuel, which may be anthracite coal, and urged by a blast, affords the requisite heat; the opening for introducing the fuel being secured by a cast-iron cover, with a flange descending into a groove which may be kept filled with water or sand to prevent the escape of hot gases.

The fire by which the smelting of the roasted ore is effected is similarly constructed, and the combustion maintained by a blast of hot air. Though the plan as detailed in the English system is followed, yet the details are very different; the receptacles for the reception of the roasted ore and coal are constructed in the form of a trapezoid, the front part being movable when it is necessary to charge or clean out the retorts; but during the distillation it is securely luted in its place. Two ranges of retorts are placed back to back in a gallery, and the heat from the fire conducted beneath and over them by a proper disposition of the flue; and for the purpose of economizing heat, the patentee directs that the retorts be so fixed that they may be heated by a fire from both ends of the gallery. A pipe opening into the retorts, and leading to receivers in a confined arch beneath the hearth, serves to carry off the distillate or zinc. When charged and in working condition, the retorts are closed in by an iron door before each; the space above the retorts wherein the ore is previously heated, is likewise approached by sliding doors, with the view of

rendering the introduction of ore and its withdrawal more easy.

In GRAHAM's patents, sealed in 1844 and 1845, the system of distillation *per descensum* is adopted; improvements being claimed for the arrangement of the apparatus and furnace, as well as for the method of making the cylinders or retorts in which the decomposition of the prepared ore is carried out. The mixture which the patentee finds most suitable for the body of the refractory cylinders just mentioned, consists of one and a half hundredweight of Ceylon black lead; six hundredweight of Stourbridge clay; and one hundredweight of potsherds. These ingredients should be well pugged and tempered, and cut into pieces of convenient size, care being taken that no excess of moisture be used that would prevent the proper cohesion and tenacity of the mass when ramming it into the mould. Fig. 644 represents the furnace and the position of the cylinders and other objects. A, A, are a series of pots, of which the number shown in the furnace is sixteen, but more or less may be employed, according to circumstances. The heat from the fireplaces, B, B, enters into the

Fig. 644.



arched chambers, C, C, and circulates round the cylindrical retorts let down through the arches, D, D, and thence into the flues, as shown by the arrows, and finally by the openings, F, F, into the chimney. The pots, A, A, rise above the arches, D, D, and pass through the covering of brickwork, E; in like manner their outlet penetrates the bed of the arched chamber of the furnace, and opens into the receivers, G, G, beneath, through movable pipes, J, J, and stationary ones, I, I, the latter are constructed of iron and lined with clay, or have a movable clay cylinder fixed within them; they have an iron flange of two inches built in and through the bed of the furnace, in which is a projecting ring or groove, Z, Z, to receive an iron ring that forms the projecting rim just referred to, and which fits into a corresponding depression in the bottom of the pot, and thereby forms, with the aid of a little luting, a tight joint. Y, Y are rings made of fireclay and potsherds, built into the bed of the furnace, flush on the outside, leaving a space of one inch and a half inside, as shown, to form a seat for the pot. W, W are holes in the walls of the furnace, which admit of making an inspection of the pots when necessary.

In charging the pots, the pipe, J, is stopped from

beneath the furnace, and a man holds steady the internal tube, H—which has its top covered—until some of the charge is introduced; the remainder is then filled in without fear of disturbing the position of the pipe. The cover is now placed on the pot and luted, and the plug securing the pipe, J, withdrawn, and the distillation allowed to proceed by urging the fires, B, B, B. When all the metal has been drawn off, the refuse matter remaining in the pots may be cleared away by removing the cover and the internal pipe, and poking it out through the pipe, J, into the subjacent chamber.

In the other details the directions which the patentee gives are analogous to the general routine, already sufficiently described.

Mr. CROCKFORD of Holywell, Flintshire, has latterly patented a method of roasting blende preparatory to its smelting, by which all the sulphur is obtained as sulphuric acid. This he effects by employing a furnace the heat of which passes beneath the floor on which the powdered blende rests. At one end of this furnace, the blende is continually introduced in small portions at a time; and in its passage from this to the discharging end of the chamber, in addition to the heat from the floor, it is acted upon by a current of superheated air, in order to convert the sulphur into sulphurous acid. The eliminated gases may be conducted into an ordinary leaden chamber, and nitrous vapor and steam supplied from other departments in the usual way, to convert them to sulphuric acid.

After the depuration of the zinc distilled from the ore it is sold to the manufacturer, or immediately applied to one or other of the many purposes for which this metal is now so generally used. The working of zinc into useful articles was formerly regarded as a difficult operation, owing to its brittleness when worked at a high temperature; by later improvements, however, it can now be rolled and modelled into any desired shape as easily as any other metal. Preparatory to rolling the zinc, the ingots which come from the smelter are melted in pots placed in a reverberatory, such as is represented in Figs. 630 and 631. The iron pots, which are very thick, are rapidly attacked by the zinc, an alloy of the two metals being formed, which is considerably less fusible than the zinc alone, and therefore adheres to the sides of the melting pot. Besides being less fusible than zinc, it is considerably harder and more brittle, and hence, when a small quantity of it gets diffused through the metal in the casting of the plates, those portions do not laminate under the rollers, but break, and thus a hole is produced. All the fusible metal is first cast into moderately thick rectangular plates, which are passed under rollers of the ordinary kind as they cool. During the lamination it is necessary to heat the metal from time to time to a temperature ranging between 270° and 300°, passing it, after each heating, under the rollers. By repetitions of these operations, and keeping the metal as near 212° as possible, the sheets may be reduced to any degree of thinness. Sheets of zinc, manufactured in this way, are in very extensive use for roofing, and generally for applications requiring much exposure to the influence of the air. The metal is also formed

into water-tanks, baths, spouts, pipes, &c., and is much used for covering or *galvanizing* iron, so as to render it less liable to oxidize when exposed to the action of the air. It is valuable for the positive plates in galvanic apparatus, for the engraver in the department known as zincography, and latterly it has been advantageously applied in the separation of silver from its alloys with lead.

ALLOYS OF ZINC.—The principal alloys of zinc are those which it forms with copper, iron, and tin. Those with copper, the reader will find described under *Brass*, in the article COPPER, and the others will be briefly described here. With iron zinc forms a hard, brittle alloy, at a moderately low temperature, but in proportion as the amount of one or other of the metals is increased, these qualities disappear, and the zinc retains its ductility, or the iron seems to acquire greater tenacity. The ductile state is exemplified in the ordinary zinc of commerce, which retains a quantity of iron, sometimes from one to two per cent., and the second or tenacious state is well illustrated by the experiments of NASMYTH upon galvanized iron, the results of which showed that this alloy welds well, and is not only fully as ductile as the best iron, but acquires greater strength or tenacity.

The experiments were made with some zinced wire rope, which was worked up and welded into a bar. It was observed that, although the iron wire was quite covered with the zinc, the portion of the latter metal which was retained at the welding temperature of the iron, or even the portion of oxide of zinc produced, offered no impediment to the welding. The metallic bar produced was remarkably tough, silvery-grained, and withstood punching, twisting, splitting, and binding, in a manner which showed that the iron was not only excellent, but actually improved in quality in a considerable degree. Another trial was made by welding a pile of clippings of zinced iron plates, as in the preceding experiment. The presence of the zinc seemed to offer no impediment to the welding of the iron, and the bar produced presented, on being fractured, a beautiful silvery grain, as good, if not superior, in aspect to the finest samples of *low-moor*, or *bowling* iron. Bars or *blooms* of the alloyed iron, rolled into rods and tested in the cable-proving machine, indicated from five to ten per cent. more strength than the best samples of wrought-iron; thus evidently showing that, so far from being injurious, a small amount of zinc alloyed with iron has the contrary effect. Bars of iron, prepared according to the last-mentioned process, were heated to the temperature of welding, as when converting them into sheathing in the usual manner, on drawing them from the fire, a handful of zinc filings was thrown on the welding surface, and the welding proceeded with. In this severe test no apparent impediment to the process resulted, the iron welding as well as if no zinc were present. Judging from the appearance of the metal welded up from the zinc-covered iron scraps, not only as respects its clear silvery aspect, but as to the increase of strength which it exhibited under proof, it may not be unreasonable to infer that some important improvement might be made in the manufacture of iron by the actual introduction of metallic zinc in some one or other of the

stages of its production; as, for instance, in the puddling furnace. What may be the nature of the action of the zinc has not yet been defined, but the foregoing experiments prove that, so far from being prejudicial to the quality of iron, the zinc appears to have rather an improving effect, and that to such an extent as to lead to the hope that some of the intelligent iron manufacturers may give the inquiry attention, so as to prove by experiment in the puddling furnace, or at any other stage of the process, whether the benefits above mentioned can be realized on a large scale. It may be stated, as a curious corroborative fact, that the strongest cast-iron made in Belgium, and selected for the manufacture of guns, is made from an iron ore in which a compound of zinc forms a considerable portion. Whether the superiority of this iron is due to the presence of zinc, is a question; but the results above detailed would tend to lead to the supposition that such may be the case.—*Ure*.

The results of NASMYTH, recorded above, are opposed to those of GEHLEN, who states that when cuttings of zinc and iron are ignited together, part of the zinc evaporates, while the rest penetrates the iron and makes it denser and very brittle. Doubtless the difference in the results must be attributed to the relative proportions of the respective metals in the alloy. The hard, brittle compound of zinc and iron produced in the pots where zinc has been melted for a long time, or in which the zinging of iron plates has been effected, was examined by BERTHIER, who describes it as a bright crystalline body, having a mammillated texture, and composed of concentric layers, very hard and brittle, and less fusible than pure zinc. It dissolves readily in dilute nitric acid, and leaves a micaceous residue of a non-metallic nature, which he terms pure plumbagine, produced, doubtless, either from the carbon employed in the reduction of the zinc ores, or from the cast-iron of the pot. Its density was 6.7, and its composition—

	Centesimally.
* Zinc,	94.76
Iron,	5.00
Plumbagine, or graphite,	0.24
	<hr/>
	100.00

Galvanized Iron.—The composition which forms such an extensive article of commerce and general application in the construction of corrugated roofing, and, in fact, entire buildings, spoutings, ships' sheathing, buckets, and various articles in household use, consists of iron plates coated with zinc, and sold under the above inappropriate title. Iron, though possessing so many admirable qualities, such great tenacity, infusibility, and the very important one of welding, is, unfortunately, rapidly acted upon by air, moisture, and dilute acids, to such an extent as greatly to impair its utility. It possesses the property, however, of combining with other metals, and hence it can be readily coated with such; but those metals which possess the persistent qualities that iron wants, are too dear, and therefore their general application is opposed by the great expense which their use would involve the manufacturer and consumer. Coated iron is familiar to most

people in the form of tinned iron plates, or *sheet tin*; but even this material would be too expensive for many of the applications in which iron might be employed with advantage could its oxidizing tendency be overcome. Zinc offers a cheaper substitute, and of late years the production and application of galvanized iron is on the increase. Although MELOUIN discovered the method of preparing zinc-coated or *white* iron so early as 1742, still its application did not receive much attention, till of late years SOREL drew attention to the manufacture; but MELOUIN's directions, with slight modifications, are followed even at present in the manufacture of this article. The iron to be covered is deprived of its coating of oxide by an acid bath, composed of sulphuric acid and water, or of hydrochloric acid, or a mixture of equal volumes of the two acids and water, in which it is immersed for a short time; it is then scrubbed with sand or emery powder until the surface is cleaned; after which it is immersed in a concentrated solution of chloride of ammonium, taken out, and subsequently introduced into a bath of melted zinc, covered with fatty matter, or colophony, to prevent oxidation, and stirred in it till the zinc forms an alloy at its surface. The coated metal is then, in some instances, introduced into a second bath consisting of melted tin, such as is used for tinning thin sheet-iron, when a slight coating of tin is formed on the exterior of the plate or bar. Of late years this second bath is generally dispensed with; a few pounds of tin being added to the zinc bath to produce the same effect.

According to MALLET's specification, the plates or bars are immersed in a cleansing bath, composed of equal parts of sulphuric acid, hydrochloric acid, and water in a warm state. After immersion the scales are detached by hammering and scrubbing the plates with emery and sand, and a thoroughly clean surface produced. It is now to be immersed in the preparing bath, composed of a saturated solution of chloride of zinc and sulphate of ammonia; after which it is transferred to a bath formed of six parts and a half of zinc and one of mercury, heated to the melting point of the former metal; in addition to which the patentee directs the addition of one pound of potassium or sodium to every ton of the preceding amalgam. When the immersed iron has attained the temperature of the bath, namely, 680°, it is withdrawn, and is found coated with a metallic layer, of which zinc forms the principal constituent. The affinity of the above alloy for iron is so great that it entirely disintegrates the iron plates, or other articles of this metal when they are thin, or possess but little body; and to guard against this inconvenience, the patentee suggests that some wrought-iron should be allowed to dissolve in the triple alloy previous to the introduction of small articles, such as wire, nails, light chains, and similar objects for galvanizing. Another means of coating iron with zinc is by electricity, and the use of a bath formed by the solution of freshly precipitated oxide of zinc in a saturated aqueous solution of sulphurous acid, or of that of the double chloride of zinc and ammonium. A moderately dilute bath and a weak current answer best. This method is not advantageous in a manufacturing sense,

the simpler mode of immersion being more expeditious and less costly.

Though iron coated with zinc is unquestionably better calculated to resist atmospheric influences without rusting than when it is without such covering, still zining it is very far from being a uniformly successful protection against its oxidation, and in some cases it increases rather than diminishes this tendency of the iron. Professor CALLAN proposed an alloy of lead and antimony as a substitute for the zinc; but though the disadvantage experienced in many instances as resulting from the employment of zinc are certainly diminished by the use of the alloy, still the cost of the latter precludes its adoption.

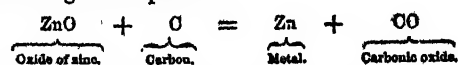
Applications of Zinc.—Besides its long-practised application in the production of brass and other alloys, such as German silver, tutenag, *et cetera*, which the reader will find described under COPPER, zinc has been employed extensively in the form of sheets for the manufacture of baths, water tanks, buckets, pails, roofing, spouts, pipes; as a cheap and more durable substitute for sheet and japanned iron, such as architectural ornaments, street lamps; and for making nails, bolts, wire for preserving iron, applied in the form of wire plates to the numerous uses which are everywhere to be witnessed; as a substitute for bronze in statuary, for which purpose it has been found, irrespective of its color, to answer exceedingly well. It is also extensively employed for the positive plates of electrical batteries, for engraving music, in anastatic printing, and numerous other forms, alone and compounded with other metals. In its oxidized and salified state it has another extensive field of application, both in the industrial arts and in medicine, as will be noticed afterwards.

Assay of Zinc Ores.—The estimation of the amount of zinc in any of its ores by the dry method of analysis, is exceedingly difficult. As, however, the metallurgist may desire to have an approximation of the quantity of metal which he can probably extract from any ore, the following brief statement of the operation is submitted here, reserving fuller instructions for the analysis of zincous bodies in general for the end of the article.

BERTHIER, who has made numerous experiments on the subject of the assay of zinc ores, divides the latter into four classes, for each of which a particular method must be pursued. These are, firstly, ores in which the zinc exists as *oxide*, or *carbonate of the oxide*; secondly, those in which the zinc exists wholly or in part as *silicate of the oxide*; thirdly, ores in which the zinc is entirely or in part in the form of *sulphide*; and fourthly, *alloys* of zinc.

To reduce ores of the first class, it is only requisite to mix them intimately with charcoal, and expose the assay for a sufficient time to a white heat in an earthen retort, having a long neck kept sufficiently cool to condense the metallic vapors that are expelled by the heat from the reducing mass. Care must be taken that no air be admitted into the retort, for this would induce the combustion of the metal while in a state of vapor; its neck should therefore terminate in a small opening, or an adaptor of glass drawn to a point be fixed to it

by luting. During the reduction the following simple interchange takes place:—



Even when the reduction is thoroughly effected, it is most difficult to detach the incrustation of metal sufficiently complete for accurate determination. To facilitate this the neck of the retort is coated interiorly with plumbago to diminish the adhesion of the distilled zinc to the body of the apparatus. When all the metal is reduced and driven over, the assayer is often necessitated to break off the neck of the retort to enable him to collect the metal, and not unfrequently to dissolve the adhering particles with nitric acid, and evaporate and calcine the residue, adding the four-fifths of its weight to that of the metal already estimated.

Another process by which the estimation of the zinc may be indirectly made is given as follows:—A certain portion of flux is added to the weighed ore, submitted to the test, and the whole heated at the temperature at which the assaying of iron is usually conducted in a lined crucible. The button of slag containing granules of iron resulting from the ferruginous matter in the ore, is weighed, then ground in a mortar, and the iron, separated by a magnet, likewise weighed. After deducting the iron thus estimated from the total weight of the button of fluxed matter, the remainder is added to the oxide of iron, corresponding to the amount of this metal found as above. The combined weight, deducted from that of the dry ore and flux, leaves a difference corresponding to the zinc expelled during the assaying in the fire. Again, if the quantity of the fixed flux employed be taken from the weight of the button of slag obtained minus the iron, the difference will show the silicious, earthy, and other unreducible matters associated with the zinc.

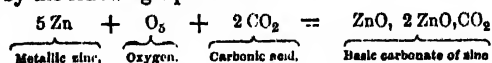
In the examination of ores of the second class, charcoal alone is insufficient to effect the decomposition, and therefore a flux is employed which, by combining with the silicious matter, liberates the oxide of zinc, and renders it subject to reduction by the carbonaceous matter. Lime or magnesia are the agents usually adopted.

When ores of the third class are under examination, the weighed sample is roasted, to convert the whole of the sulphur into sulphuric acid and partly expel it by the heat; after which the reduction is effected in the same way as directed for the determination of the metal in the first class of ores.

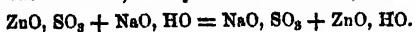
Alloys of zinc with fixed metals, or the compounds of the fourth class, are examined by adding a determined weight of fixed flux, mixed with some charcoal, and heating in a lined crucible at the temperature of the iron assay; all the zinc is volatilized, and from the loss of weight so sustained the amount of zinc is estimated approximatively. If the alloyed metal be of a volatile nature, this course will not afford true results, and the estimation of the constituents of the compound must be effected by the humid assay, which indeed is the most trustworthy, and in the end the most expeditious for the analysis of all zincous compounds.

COMPOUNDS OF ZINC.—Zinc is capable of uniting with almost the whole of the metalloids and salt radicals, producing compounds, which in all instances are of great importance in the arts, and have consequently a very extended application. Its oxygen salts, like those of magnesia, have the property of forming saline compounds with other substances, the importance of which is entirely confined to the department of scientific chemistry connected with stoichiometry. Another remarkable behavior of zinc is, that it readily combines with several organic radicals, such as ethyl, methyl, and radicals of the alcoholic series of compounds, as shown by the very scientific researches of FRANKLAND and others. Several of the combinations of this metal are employed in medicine; and, by a remarkable coincidence, these so employed are most useful in many industrial applications. It will be sufficient to describe here the oxide, the carbonate, sulphate, acetate, and chloride of this metal.

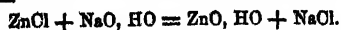
OXIDE OF ZINC.—This compound has various designations, most of them given by the alchemists. Its ancient synonyms were *nihil album*, *lana philosophica*, *flowers of zinc*, *pompholyx*, and occasionally it is still known as *flowers of zinc* or *flores zinci*. When submitted under certain circumstances to the influence of air and moisture, zinc is acted upon in various ways, all of which result in producing the oxide, or a compound from which the oxide can be readily prepared. Thus, when the metal is heated to redness in a free current of air, it burns with a brilliant bluish-green flame producing oxide of zinc. Again, if the zinc be exposed to air and moisture, it is transformed into the same compound; or if carbonic acid should be present, into a basic carbonate of the oxide. In these cases, simple and direct oxidation takes place, the oxide combining, in the latter instance, with a certain amount of carbonic acid. This is the nature of the change which is produced on the surface of zinc exposed to the air, as in roofings, *et cetera*, and which conduces so much to its preservation. It is illustrated by the following equation:—



When zinc is dissolved in sulphuric or nitric acid, the oxide is freely formed, though only in the proportion requisite to produce a salt with the acid employed. In this state it exists in the salified state, but on abstracting the acid by interposing a stronger base, such as soda, the hydrated oxide falls, thus—



The same change takes place when the solution of zinc in hydrochloric acid is acted on, although the oxide does not pre-exist in the menstruum, for at the period of the removal of the radical of the salt the oxygen of the precipitant is assimilated by the zinc, as shown in the equation—



Oxide of zinc is prepared either by the ignition of the metal in a current of air, or by its solution in acids and subsequent precipitation by any convenient agent. If pure oxide be required, the first method will not yield it unless the metal be free from all extraneous metalliferous

matters, which is never the case with the commercial article. In the second method the impurities existing in the zinc can be removed previous to the precipitation of the oxide, and consequently this method is preferred when it is important that no foreign matter should exist in the preparation.

In operating by the first method, a hessian crucible is filled with zinc to one-eighth its capacity, and then placed in a wind furnace so inclined that the lower part rests upon its edge on a piece of tile at the bottom, whilst the upper part is supported by the rim of the furnace. The fire is then urged till the crucible and contents attain a strong red or white heat. At this period a scum of oxide appears on the metal, and must be removed with an iron spatula as fast as formed, till the combustion of the zinc is completed, when a fresh charge may be introduced. The oxide as collected is placed upon an iron plate to cool, and is afterwards rubbed up with water to the consistence of a thin pasty mass, which is next diluted largely, allowed to settle for a few minutes and then decanted, more liquid being agitated again with the subsided matter, and treated, after a minute or two's repose, in the same manner. By continuing the treatment so long as the decanted liquors flow off milky, all the oxide is separated from the metallic matter which escaped ignition in the crucible, and which may be introduced with another portion of zinc to undergo fresh combustion. All the decanted liquors are collected together and allowed to subside perfectly, when the clear water is poured off, the deposit thrown upon a cloth filter to drain, and finally it is dried at a gentle heat. The yield of zinc oxide obtained in this way, when the whole of the metal is burned, will be somewhat more than the weight of the zinc employed.

When the oxide is to be prepared by the liquid process, rectified sulphuric acid, diluted with ten times its weight of water, is poured upon the zinc previously rolled into thin sheets, or granulated by pouring it whilst in a molten state into a vessel of water, employing an excess of the metal with the view of causing the foreign matters, such as lead, tin, cadmium, bismuth, arsenic, *et cetera*, to be precipitated; or a solution of crystallized sulphate of zinc in thirty parts of water may be taken, immersing in it for forty-eight hours a few thin plates of zinc, which act in the removal of any foreign bodies in the same way as the excess of metal in the foregoing method. The clear solution is decanted in either case, or strained, if necessary, and a hot concentrated solution of carbonate of soda is added to it as long as a precipitate forms. This precipitate, which settles much more readily when thrown down from hot solutions than from cold ones, is now washed with hot distilled water by decantation, till no further trace of sulphuric acid is detected in the washings with a solution of chloride of barium. After thorough washing it is collected on a cloth filter, allowed to drain, pressed and dried, and finally heated to redness in a hessian crucible, till the whole of the carbonic acid is expelled, as evidenced by its not effervescing on the addition of dilute acid.

Properties.—Oxide of zinc is a white, tasteless, inodorous powder, which at red heat acquires a yellow

color, that vanishes on cooling. When subjected to a higher heat it melts into a yellow glass, and at a sustained white heat volatilizes. It is insoluble in water, but readily soluble in acids, giving rise to the corresponding zinc salts. When freshly precipitated, oxide of zinc is readily soluble in alkaline solutions, as also in concentrated ones of sesquicarbonate of ammonia, producing compounds in which it assumes the characters of a salt radical that are called *zincates*. Heated with charcoal it is readily reduced to the metallic state.

Uses.—Oxide of zinc is employed principally in medicine. Latterly, however, it has been successfully introduced as a substitute for carbonate of lead—white lead—in the manufacture of paint; and to meet this extended use several processes have been devised for its preparation, to which reference will be made presently. The oxide has been prescribed in some cases of epilepsy, chorea, hysteria, catalepsy, and whooping-cough, as well as in some painful affections of neuralgia and gastrodynia, with occasionally good effect, though its frequent failure has shaken the confidence of practitioners in its efficacy. It has been found serviceable in five-grain doses, combined with extract of henbane or hemlock, in colliquative perspiration. It is useful as a desiccant to allay or prevent excoriation in children, as well as in cases of chronic skin diseases, attended with profuse secretion, and also in other ailments of a similar nature. In large doses, oxide of zinc acts as a slight irritant and causes vomiting, and by long-continued use it acts as a slow poison.

Oxide of zinc is composed of—

	Atomic weight.	Centesimally.
1 Eq. of zinc,	32.0	50.0
1 Eq. of oxygen,	8.0	20.0
	40.0	100.0

Its chemical symbol is ZnO.

CHLORIDE OF ZINC—*Muriate of zinc; butter of zinc.*—This compound of zinc has long been known and applied in medicine. It is prepared by adding hydrochloric acid of specific gravity 1.130 to granulated zinc portionwise, and applying heat till the latter is dissolved. Four parts and a half of acid are required for every part by weight of metal for its perfect solution. A few fragments or thin plates of zinc are introduced into the solution, and set aside for twenty-four hours, during which time any lead, tin, antimony, cadmium, or other metals of this class that may be present in the liquid, are precipitated; after this, the clear liquid is separated by filtration from the deposit that may have formed, and about one-sixteenth of its bulk precipitated, with a very slight excess of carbonate of soda, the basic carbonate separated and well washed while on the filter, and then introduced into the remainder of the liquid. Chlorine, generated in the usual way from binoxide of manganese and hydrochloric acid, is now passed into the menstruum till it smells of the gas. A further period of twenty-four hours is given to the liquid to stand, and if, after this period, a portion of the clear solution exhibits any indication of the presence of iron, either by giving a bluish-black color with tincture of galls, or by striking a deep blue with ferrieyanide of potassium—red prussiate. A further

portion of the liquid is taken and precipitated with carbonate of soda, as above, and the mass so obtained, after thorough washing, is added to the liquor containing the zinc, allowed to digest for a further period, and afterwards tested for the presence of iron in the manner indicated. If necessary, the process is to be repeated a third and a fourth time, or until the whole of the iron is separated in the form of sesquioxide; but it rarely happens that this metal remains after the second digestion. After filtering from the formed deposit, the liquid is evaporated in a porcelain or hard stoneware dish on the sand-bath, taking care, as it becomes denser, to keep the contents of the vessel constantly stirred, till the whole of the water is expelled. Chloride of zinc remains, and should be transferred, whilst still hot, to well covered vessels for use. When it is necessary to deprive it of the whole of the water, the residue from the evaporation should be introduced into a glass vessel with a narrow neck, and heated at a higher degree, till the chloride of zinc begins to distil, at which period the fused matter is poured out on a slab, and when cooled broken into fragments, and preserved in well-stopped bottles.

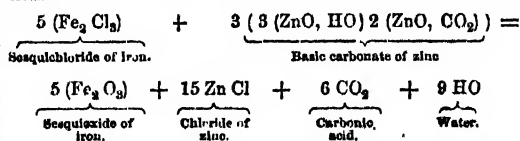
In the preceding process the action of the acid is simple and well understood, its chlorine uniting with the metal, while its hydrogen is disengaged, thus—



The action of the chlorine is to convert the iron, which always exists in commercial zinc, from the state of protochloride to which the hydrochloric acid reduces it, to that of sesquichloride, as shown in the equation—



with the view of precipitating it subsequently with the basic carbonate of zinc— $3 (\text{ZnO}, \text{HO}) 2 (\text{ZnO}, \text{CO}_2)$ —produced by the carbonate of soda in the portion of the liquid submitted to its action. The manner in which its separation is chemically effected may be represented thus—



that is, three equivalents of the basic carbonate convert five of the iron salt into five equivalents of insoluble sesquioxide, being themselves reconverted into fifteen equivalents of the chloride of zinc by the assimilation of the chlorine from the iron compound.

Chloride of zinc may be prepared by other processes, such as heating equivalent weights of oxide of zinc and chloride of ammonium, or by distilling a mixture of dry sulphate of zinc and chloride of sodium in a retort, the substances being employed in the ratio of their equivalent weights. In either case chloride of zinc results, the change in the former being $\text{NH}_4 \text{ Cl} + \text{ZnO} = \text{NH}_3 \text{ O} + \text{Zn Cl}$; and, in the latter, $\text{ZnO}, \text{SO}_4 + \text{Na Cl} = \text{Zn Cl} + \text{NaO}, \text{SO}_2$. The salt in the first formula remains after the expulsion of the ammoniac; but in the second instance it distils over, leaving the

sulphate of soda in the retort. Preference is, however, generally given to the method of preparation by solution.

Properties.—Chloride of zinc, deprived by fusion of all moisture, is a whitish-grey, semitransparent soft mass, like wax, that melts at a temperature below redness, and at a higher degree of heat sublimes, being at the same time partially decomposed into a basic chloride of zinc and an acid salt, which collects in crystalline needles in the receiver, and oxide of zinc retaining a little of the chloride that remains in the retort. Exposed to the air, the salt rapidly attracts moisture and deliquesces. It has a burning, nauseous, saline taste, even in highly dilute solutions. Alcohol and ether readily dissolve it, the solutions manifesting an acid reaction. It unites with chloride of ammonium and chloride of potassium, and forms definite compounds with them, likewise with albumen and gelatin, producing difficultly soluble precipitates. The alkalies and alkaline carbonates decompose it, giving rise to precipitates of oxide and basic carbonate of zinc, according to the agent used, but which precipitates, as stated under *Oxide of Zinc*, are soluble in an excess of many of these reagents, owing to zincates of those bases being formed. Sulphuric acid readily converts the chloride into a sulphate of zinc, with evolution of hydrochloric acid. The pure salt has a composition corresponding to the symbol $Zn\ Cl$, being composed of—

	Atomic weight.	Centesimally.
1 Eq. of zinc,.....	32.0	47.40
1 Eq. of chlorine,.....	35.5	52.593
	67.5	100.000

The composition of the hydrated salt is $Zn\ Cl, HO$; it is crystalline, and contains, according to SCHINDLER, in one hundred parts—

	Centesimally.	Schindler.
Zinc,.....	32.0 = 41.83	39.80
Chlorine,....	35.5 = 46.40	43.81
Water,.....	9.0 = 11.77	16.39
	76.5	100.00

Uses.—Owing to its physiological effects, the chief use of chloride of zinc is in medicine; but latterly it has been successfully introduced as a disinfectant, and likewise for impregnating wood in order to preserve it from decay or putrefaction. Its use has been much extended in the first application by its qualities as a caustic or escharotic, destroying the life of the part with which it comes in contact, owing to its combination with the albumen and fibrin of the tissue, which substances appear in the form of an eschar some time after. Many prefer chloride of zinc in this capacity to nitrate of silver, and even to chloride of antimony, as it penetrates further, and leaves the wound or sore in a more healthy state after the removal of the eschar. When taken into the system, chloride of zinc acts, in large doses, as an irritant or caustic poison, and affects the nervous system. It produces a burning sensation in the stomach, nausea, vomiting, anxiety, short breathing, cold sweats, fainting, and convulsions. In very small doses, none of these effects are attendant upon its use.

Sir WILLIAM BURNETT introduced a concentrated
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solution of this compound some years ago, as a disinfecting and antiseptic fluid. The liquid contained about one-fourth of its weight of the salt, and had a specific gravity of 2.0. Its antiseptic qualities depend upon its power of uniting with animal tissues, and forming permanent bodies with them; and hence its use in preserving anatomical subjects for dissection; its disinfecting quality arises from its power of decomposing sulphide of ammonium and sulphide of hydrogen to some extent. It is inferior, however, in this respect to a solution of chloroxide of calcium—bleaching powder—and several other combinations, as stated under *Disinfectants*—owing to the latter being not only capable of arresting gaseous emanations, but also of disseminating a disinfecting gas into the air which arrests any foul odor immediately.

SULPHATE OF ZINC—Zinc vitriol; white vitriol.—This salt, which is said to have been known at the end of the thirteenth century, has been long manufactured on a large scale at Goslar in Germany. It was long erroneously considered as a modified sulphate of iron, but this notion was abandoned when the true metallic nature of zinc became known. It is much more important than any other saline combinations of the metal, as well for its cheapness as for being the means of preparing the other compounds of zinc, and likewise for the extended uses to which it is applied in the arts and in medicine.

Preparation.—At Goslar, where sulphate of zinc was first extensively manufactured, as well for the preparation of Nordhausen vitriol as for application in the medicinal art, the following process was adopted:—

The natural deposit of ore, consisting of sulphates of zinc, lead, copper, silver, and iron, was assayed to obtain the portions richer in zinc; these were submitted to a roasting operation in heaps, during which the sulphur was converted into sulphuric acid, and by this the metals were changed into the corresponding sulphates; the mass was then lixiviated, and the soluble salts, consisting of sulphates of zinc, iron, cadmium, copper, and silver, washed out, and afterwards evaporated till the sulphates crystallized. The impure salt, after slight washing, was heated to the melting point, and the whole, or chief, part of its water of crystallization expelled. On allowing the mass to cool at this stage, it formed a white opaque granulated substance resembling sugar. At a later period this product was freed from portions of its impurities by re-solution in water, and introducing into the lie fragments or plates of zinc, which were allowed to remain in contact with it for a longer or shorter time. After drawing off the clear liquid, it was evaporated, and the zinc salt crystallized out as before. This method is still practised, not only at Goslar, but in several other localities where blende is abundant.

Sulphate of zinc is obtained at present as a secondary product from the acid liquors of galvanic batteries employed in developing electricity, as also from the liquors remaining after the precipitation of copper on the large scale from its solutions, by metallic zinc.

The pure salt may be obtained by treating commercial, or purified zinc, in a divided or granulated state, with sulphuric acid diluted with fifteen times its weight

of water, in a leaden vessel, using the acid while still warm; three parts of rectified acid of specific gravity 1·84, are required to convert two parts of the metal into a sulphate. The mixture is sustained at a gentle heat in order to promote the solution, and with the same view the contents of the vessel are agitated occasionally. After the solution is effected, a quantity of metal, about one-eighth of the portion dissolved, is introduced into the liquid, and left to repose during thirty to forty-eight hours, the slight heat being still maintained. By this treatment the lead and other less oxidizable metals are precipitated, and are separated by filtering the liquid while still hot. The filtrate is now largely diluted with water, and a portion of it taken, precipitated with carbonate of soda, as stated under the preparation of chloride of zinc, filtered, washed, and added to the remainder of the solution of the sulphate. Chlorine is then transmitted into the mixture till the protosalt of iron present in it is converted to a sesquisalt; after which the whole is allowed to stand till the iron falls in the form of sesquioxide. The various changes by which the purification of the salt is effected in this instance, are analogous to those specified under *Chloride of Zinc*, and therefore need not be detailed. After filtering the liquid from the deposit of sesquioxide of iron, it is evaporated till a pellicle begins to form on the surface, when it is permitted to rest to allow the salt to crystallize. A second crystallization removes all traces of impurities, but this is rarely required.

Properties.—Sulphate of zinc crystallizes in colorless, transparent, right rhombic prisms, containing seven equivalents of water of crystallization. In this state it is very soluble in water, requiring somewhat less than its weight of cold, and considerably less than its weight of the boiling liquid; thus, according to KARSTEN, one thousand parts of water at 63·6°, dissolve nine hundred and twenty-three parts of this salt, forming a solution, the specific gravity of which is 1·4353. DUMAS states that one hundred parts of water, at the ordinary temperature, take up one hundred and forty parts of the sulphate; while other authorities assert that not less than two and one-third parts of water are necessary for the liquefaction of one of the salts, which is evidently erroneous. Boiling water takes up a much larger quantity of the salt, and even alcohol dissolves traces of it. Sulphate of zinc, according to the circumstances under which it is prepared, is found associated with different quantities of water of crystallization, varying from one to seven equivalents; but the compound crystallizing from its solutions at temperatures below 80° to 86°, always assimilates seven equivalents of water. This salt effloresces slightly in the air; exposed to a heat of 212° it loses 37·3 per cent. of moisture, or six equivalents, the last equivalent being obstinately retained till the heat rises to 451°. By the sudden application of a high temperature the compound at first fuses, and after the expulsion of the contained water, decomposition of the salt follows; anhydrous sulphuric acid, sulphurous acid, and oxygen being eliminated, while a highly basic salt remains. On continuing the heat, however, till it approaches to whiteness, only pure oxide of zinc is left. Heated with charcoal at a red

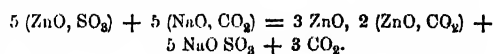
heat, it is reduced to the form of sulphide; but at a sustained white heat, the metal is isolated and volatilized in the form of vapor. Anhydrous sulphate of zinc, on being exposed to moist air, readily assimilates its full complement of water of crystallization with reagents. It affords the usual reactions of oxide of zinc in a salified state, and is capable of forming numerous double salts with other bodies. Sulphate of zinc, in its crystallized form, is represented by the formula $\text{ZnO}, \text{SO}_3, 7 \text{H}_2\text{O}$, and is composed of—

	Atomic weight.	Centosimally.
1 Eq. of oxide of zinc,	40·0	= 27·972
1 Eq. of sulphuric acid,	40·0	= 27·972
7 Eqs. of water,	63·0	= 45·056
	143·0	100·000

Uses.—This salt is used in medicine, in consequence of its physiological effects, which are, when administered in small doses, of an astringent, antispasmodic, and tonic nature; whilst taken in large quantities it is poisonous, causing vomiting, purging, coldness of the extremities, and a fluttering pulse. In full doses it acts as a safe emetic, but care should be taken that it be thrown off the stomach, for if retained for any length of time it occasions nausea and prolonged retching. In this capacity of emetic it is of great use where poisoning is suspected, as it acts rapidly. Sulphate of zinc is frequently used, owing to its astringent and caustic properties, in diseases of the eyes, and generally with good effect. In some cases it is used by dyers as a mordant; also as an oil drier for painting.

CARBONATE OF ZINC.—The preparation of the neutral carbonate of oxide of zinc is somewhat difficult, owing to the feeble affinity of the oxide for carbonic acid. If, however, the precipitate which occurs on adding a solution of bicarbonate of soda or of potassa to a solution of zinc be, after washing, disseminated in water, and carbonic acid charged into the liquor, the precipitate is dissolved in the form of a bicarbonate, and on evaporating the liquid in an atmosphere of carbonic acid, the neutral or monocarbonate of oxide of zinc is obtained. Its formula is $\text{ZnO}, (\text{CO}_2)$.

The ordinary carbonate of this oxide is a basic compound, containing five equivalents of base to two of acid. It is obtained by adding a solution of carbonate of soda to one of sulphate of zinc, taking care that the latter is in slight excess. The change which succeeds may be exemplified thus—



When the precipitant is in excess, a portion of it combines with the basic salt and cannot be removed by washing. For this reason carbonate of ammonia is sometimes preferred, only an equivalent quantity being employed, so that excess of the salt, which would dissolve a part of the zinc carbonate, is avoided. The precipitate in either case is washed well and dried at 212°.

Properties.—It is a loose white powder resembling the carbonate of magnesia of the shops, almost insoluble in water, easily soluble in acids with evolution of carbonic

acid, and converted by a red heat into oxide of zinc. Like the oxide it is readily reduced by carbon at a red heat. MOORE asserts that several of the varieties sold in the shops as calamine or carbonate of zinc contain no zinc whatever, but mixtures of carbonate of lime, sesquioxide of iron, and sulphate of baryta. When a sample of the zinc carbonate is suspected to be fictitious, its purity is readily ascertained by dissolving it in dilute hydrochloric acid, and adding an excess of carbonate of ammonia to the liquor. It should be wholly soluble in the acid, and the precipitate at first formed in the second case should be dissolved by the excess of the ammoniacal salt. A residue on the one hand, or a persistent precipitate on the other, indicates adulteration.

Uses.—Physiologically the carbonate of zinc has the same properties as the oxide, and is applied medicinally in like cases. In the arts, this compound has of late years, together with the oxide, acquired some importance as a substitute for white lead in painting.

ACETATE OF ZINC.—The reader will find this salt described in Vol. I. page 48. It may be stated here, however, that it can be conveniently prepared from the carbonate of this base and acetic acid. Two parts of the carbonate are heated with successive portions of acetic acid of specific gravity 1.045—containing sixty-four per cent. of water—till complete solution is effected. About five parts of acid are required. The solution is filtered while warm, and set aside to cool for a day or two, after which period it is decanted and concentrated to the crystallizing point, when, on cooling, the acetate will deposit. Acetate of zinc possesses a slight odor of acetic acid and a bitter saline nauseous taste. On being heated it fuses with the loss of water, and at length blackens, giving off the usual empyreumatic products resulting from the igneous decomposition of the acetates; and if the temperature be very elevated, the oxide of zinc will be likewise reduced.

Acetate of zinc is soluble in three parts of cold and in half a part of boiling water; in thirty parts of alcohol of eighty per cent. at the normal temperature, and in one part at the boiling point. The solutions have an acid reaction.

Uses.—Physiologically considered, the acetate of zinc is reputed to have the same properties as the sulphate, but some French writers deny that it has a poisonous effect even when administered in large doses. The salt is used by dyers as a mordant.

ZINC-WHITE.—This pigment, to which considerable attention has been given of late years, is either the anhydrous oxide, the hydrate oxide, or hydrated basic carbonate of zinc. Its whiteness is equal to that of white lead, and not being tarnished like the latter by sulphurous vapors, it has been proposed to introduce it as a substitute for white lead in painting, especially as it affords a more permanent color, is cheaper, and does not involve the great risk and sacrifice of life which, however carefully the preparation of the carbonate of lead may be conducted, is occasioned among the workers engaged in that manufacture. The principal objection to its general adoption is, that the paint compounded with it is less drying than those in which lead constitutes the basis, and also that it does not cover or spread so

perfectly as white lead; or, in the language of the painter, that it does not possess sufficient *body*. With regard to its non-drying qualities, improvements have been suggested which, if acted upon, would, in a great degree, obviate this objection; and as to the want of body, the painter can well afford to spread a thicker layer of the zinc-white, seeing that a given weight of the latter is considerably more bulky than the same quantity of the former, in consequence of the lesser density of zinc, as well as its much lower atomic weight, which is to that of lead in the proportion of thirty-two to one hundred and four.

GUYTON DE MORVEAU was the first to propose the substitution of oxide of zinc for the basic carbonate of lead in painting. LASSAIGNE likewise drew attention to the subject about 1821, and has lately communicated the fact that an oil painting finished at that time with oxide of zinc has hitherto retained its brilliant whiteness. The manufacture of the zinc-white owes much, however, to M. LECLAIRE, who was among the first to establish its manufacture on a large scale for this purpose. More recently several patents have been taken in England for the preparation of the oxide of zinc for the painter's use, and some of these will be referred to further on.

Manufacture.—At first metallic zinc was the material from which the zinc-white was prepared, the simple change effected being merely the dissipation of the metal in the form of vapor. While in this state, and still at a high degree of heat, the introduction of a current of air causes the metallic vapor to ignite, producing oxide of zinc in a finely-divided white powder, which, when collected, forms the substance in question. The arrangement by which this change is effected is shown in Figs. 645 to 646. In Figs. 645 and 646, the retorts from which the zinc is distilled are represented in section and elevation. They are similar to gas retorts, and are depressed cylinders, *a a*, of refractory clay, such as that of which glass pots are made. Their length is about

Fig. 645. Fig. 646.

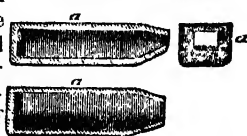
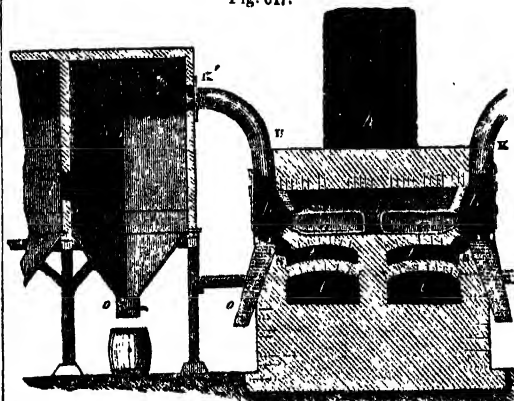


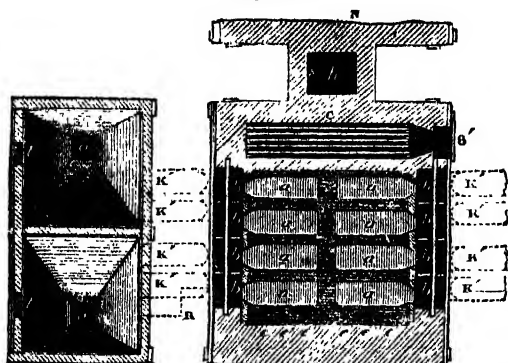
Fig. 647.



twenty-eight inches, their breadth ten inches, and their height about six inches; the walls are two and a

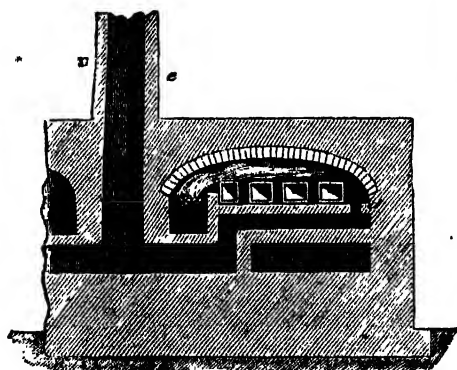
quarter inches in thickness; the aperture, *b*, which serves the double purpose of introducing the pigs of zinc, and allowing the metallic vapors to escape, is four inches in breadth and two in height. Eight or ten of these are placed in a double range, back to back, in a reverberatory, represented in plan and section in Figs. 648, 649,

Fig. 648.



and 650. The fire is at *c*, the heat and flame of which pass over the cylinders and return beneath the floor of the reverberatory by the flue, *c*, *d*, *f*, *g*, *h*, into the chimney, as seen in Fig. 649. When the interior of the furnace and the retorts are observed at a reddish white heat, one or two bars of zinc are introduced into each of the retorts. The metal soon melts and enters into ebullition, the vapor being disengaged by the aperture, *b*, of each retort, where it comes into contact with a

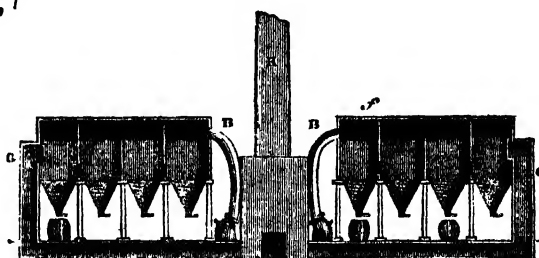
Fig. 649



current of air heated in the cast-iron pipes, *ss*, to about 570° by the waste caloric of the furnace, and enters into combustion. The metallic oxide so produced is carried along by the current of gas into the pipes, *kk*, which surmount the mouth of the retort, and is deposited in the chambers, *ll*, four of which are in connection with each other by apertures alternately at the lower and upper part of their partition walls. The disposition of the condensing chambers and other parts of the apparatus is shown in Figs. 650 and 651. Here *A* indicates the furnace, *B* the pipes leading to the chambers, the last opening in the outer one of which is covered

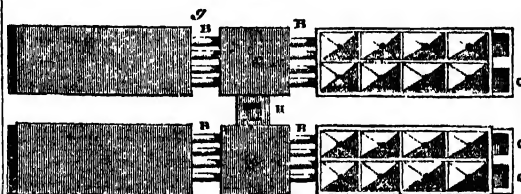
with a fine metallic gauze stretched on an iron sash or framework, for the purpose of intercepting all the particles of the zinc-white; whilst the meshes of the

Fig. 650.



wire affords sufficient space for the egress of the nitrogen and other gases into the flue or passago, *gg*, leading to the chimney, *h*. In this conduit two other screens, similar to that above described, may be fixed, but somewhat finer, to prevent the loss of as little as possible of the powder. After a while the wire gauzes become covered with the powder, but before the meshes are closed they are cleaned and replaced.

Fig. 651



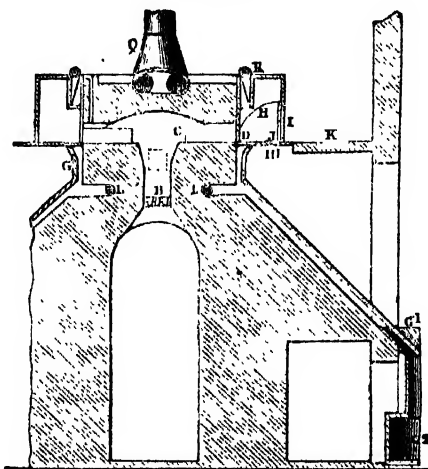
The oxide of zinc thus produced is always of good quality, unless indeed an excess of impurities exists in the metal employed. That which is inferior is always deposited in the first chamber, being impregnated with the oxides of the metallic bodies contained in the zinc, and also with a finely-divided powder of the zinc itself, in consequence of some of its vapor being carried over before it underwent combustion. In consequence of these impregnations, the powder collected from the first chamber should always be screened, and the product devoted to the commoner kinds of painting. It is necessary during the formation of the oxide of zinc, to clear the openings communicating with adjacent chambers, lest the deposition of the powder on the walls should accumulate so as to block up the passage. This is done by means of an iron rod passed through the wall, and commanding the opening. After the conversion of the charge is completed, the oxide of zinc deposited in the chambers is removed simply by placing a barrel beneath the mouth of the hopper-shaped opening in the chamber, and drawing the sliding-plate which is used to secure it while working. The zinc-white is then easily scraped into the receiver, and there reduced by pressure to the least possible volume. It is now ready for the market, or for compounding with the oil as in the manufacture of paint. Three furnaces like those described, each furnished with eight retorts,

work off from twenty-eight to thirty hundredweight of zinc in the twenty-four hours. This quantity ought to produce from thirty-five and a half to thirty-seven hundredweight and a half of zinc-white; but in practice the average yield amounts to only thirty-one and a half to thirty-four hundredweight.

Of late years several improved methods have been devised for the preparation of this substance, the most important of which, in the Editor's judgment, will now be briefly stated.

M. LECLAIRE's mode of operation is indicated in the following description and figures, taken and abridged from *Le Génie Industriel*. Figs. 652, 653, and 654 show

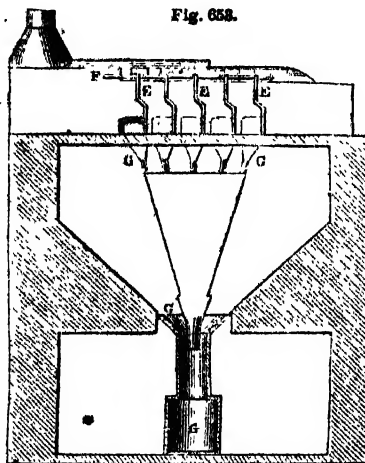
Fig. 652.



the distillatory furnace in longitudinal and transverse vertical sections and in plan. In these figures, A represents the fire-door, B the fire, and C the retorts, which are made of refractory material. Five are generally ranged at either side of the grate, but the number can be varied according to circumstances. The volatilized metallic vapors escape by the orifice, D, of the retort, before which are disposed a series of plates, E, called scrapers, attached to a horizontal iron rod, F, by similar pendant ones. By motion communicated by hand or machinery to the horizontal rod, the scrapers, E E, are moved backwards and forwards, and coming at each movement against the door of the retort, any oxide which adheres to the aperture is knocked off. The oxide and metallic vapors issuing from the retort are received in small receptacles, G G, which open into an inclined channel that terminates in another funnel-shaped conduit, G', and this leads them into the receiver, G'. It is evident that the small conduits, G G, receive only such matters as solidify in the mouth of the retort, and which from their density cannot be drawn off to the receivers by the force of the current of gases passing through this arrangement to the chambers wherein the oxide of zinc is collected. A small plate-iron cage or box, H, is fixed over the mouth of each of the retorts in order to isolate them. It rests upon a framework of metal, H', fixed into the wall of the furnace, and so constructed that it may be

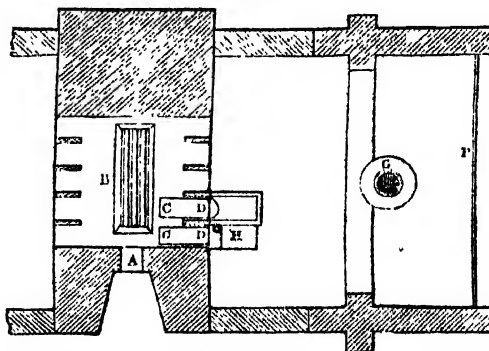
removed at will by means of a crane, or by making it slide or roll on a framework or small railway. The anterior aperture is directed towards the orifice of the

Fig. 653.



retort in such a manner that the products of the distillation empty themselves into it, and the posterior part has a door which may be opened at will. A trap-door, J, is contrived in the suspended plate, K, and which can be raised or lowered at will by an iron-wire rope passing through the posterior plate, I, of the box, H, without opening the door in this part of the latter. Sometimes, instead of lifting the trap-door, it is so formed that it can be drawn backwards when it is necessary to open

Fig. 654.



it. K designates the suspended plate upon which the box or cage is placed; it is isolated in its construction from the chamber of oxidation. Currents of cold air may be directed upon this plate in order to cool it, so as to resist the temperature of the chamber. The hot air, admitted for the combustion of the metal, enters from the pipe, L; it communicates with the passage from the retorts to the receivers, and so drives the oxide of zinc formed into the latter. In the receivers the inventor places cloths for sifting or screening the products, the floor of each being a kind of hopper, or inclined plane, whereby the product gliding over the cloth is separated into its various qualities of fineness, and received at once into separate boxes placed beneath

the sifter. In order to retain the finely-divided particles of zinc-white which arise from the agitation, cloths are suspended at regular distances. These, while they afford a passage to the gases, retain the particles of metallic oxide, and so prevent a loss of material.

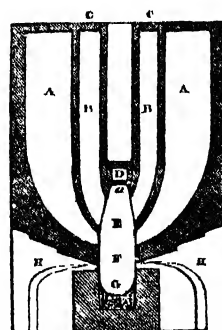
A draught pipe, Q, draws off the air and gases as well as the finely-divided oxide from the oxidising chamber through the whole arrangement. Another pipe, R, placed at the top of each retort, draws into it by a funnel-shaped opening all vapors and powder emitted from the retorts whilst they are being charged, and the draught of which, whenever it is isolated from the oxidising chamber is sufficient to draw the products through a series of chambers not shown in the drawing, having cloth screens as usual to retain the oxide of zinc. The ventilation of both the draught pipes, Q and R, is effected by means of the waste heat of the furnace.

The same inventor combines the principle of the reverberatory furnace in the distillation of zinc for the purpose of making zinc-white. In this arrangement he so disposes the retorts that the flame from the coal fire circulates round them, and then passes into a chamber over the dome inclosing the retort, where pipes may be laid for raising the temperature of the air which is forced into the space surrounding the mouths of the retorts to oxidise the zinc vapors. The oxide so produced is conducted to receiving chambers in a manner somewhat similar to the two methods already described.

ROCHAZ's patent, dated in 1849, describes a construction of furnace suited either to the conversion of metallic zinc, or of ores of this metal, into the oxide. In the first case he uses clay crucibles, and arranges them in three rows in a furnace, supporting them by two intermediate fire-brick walls and by the side walls of the furnace, and so securing the crucibles at the surface that no vapors or smoke from the fire can issue from the chamber beneath them, but must pass off through passages in the bearing walls by small flues into the chimney. A loose slab or clay tile is used as a cover for the vessel wherein the distillation is effected, and the whole is inclosed by a flat roofing of refractory tiles, well cemented and raised a few inches above the crucibles, for the introduction of air from without, for oxidising the metallic vapors. This space leads to a large chamber, in which plates of iron are suspended in a slanting direction, so as to cause the current of vapor, loaded with oxide of zinc, to take a sinuous and zigzag course in passing through it. In addition to these he fixes bands of hemp, or other textile material, at intervals transversely in the chamber, with the view of intercepting the last portions of the zinc-white. Further he contrives that the upper end of these bands shall pass through the walls of the chamber and dip into a trough of water, so as more effectually to condense the zincous vapors in the interior. He directs that the chambers more distant from the furnace be constructed of sailcloth, which affords the advantages of being easily accommodated to space, and of keeping the walls cooled by means of a copious sprinkling of water, applied exteriorly, and which causes the oxide of zinc to deposit more readily. The same patentee

claims a method for preparing the oxides from the ores by a previous roasting, and introducing them, thus prepared, with charcoal or slack, into cylindrical or square clay crucibles, somewhat similar to those employed for the reduction of the metal at Vieille Montagne, but without the condensers, opening into a closed channel in the front, through which a current of air is introduced, and which carries the oxide of zinc, resulting from the combustion of the metal, into a chamber disposed similarly to that described; likewise a blast furnace, represented in Fig. 655, for the same purpose. In this figure the mixture of roasted ore and fuel is introduced into the passages, A A, B B; others are filled with

Fig. 655.



coke or other fuel; all of which are covered with tiles, C C; R, the cavity of the furnace, which is always kept filled with fuel from the passages, B, B, and in which the reduction of the ore is effected by means of the blast introduced through the tuyere pipes, H, H, more especially in the region of F. The slags and residue descend into the cavity, G, whilst the vapors of zinc pass off by the channel or flue, D, into the condensing chamber, as soon as the stopper, A, inclosing the mouth of the chamber, E, is removed. In the latter flue they meet a stream of air that effects their oxidation. The chamber is evidently required to be more extensive in this instance, owing to the gaseous products of the combustion of the fuel being carried along with the oxide of zinc produced in the flue, D; but, excepting this inconvenience, the patentee asserts that no other will result, for all the carbonaceous or sooty products, produced in the region of the blast, are entirely reduced or consumed in passing through the column of incandescent fuel above F, so that only pure gases, which are not calculated to discolor the product, are evolved.

KNOWLYS secured a patent in 1850, in which, among other claims, is a method of preparing the zinc-white from its ores, by dissolving the oxide in sulphuric acid, and, after clarifying the solution by filtration or subsidence, precipitating the metallic oxide with a solution of carbonate of soda. The precipitate, after being washed and collected, is then dried by means of heat and pressure, and the compound so produced is either used in this state or reduced by ignition to the oxide and then compounded into paint in the ordinary way.

PROTHIEROE employs an ordinary cylindrical retort, having inlets for the passage of a current of air at the

posterior end, and another for raking out the heavy oxide which forms on the surface of the metal and the walls of the retort, the lighter and finer particles being conveyed by a pipe with the current of air to a condensing chamber, which is divided by partition walls of brick, or other material, into several compartments. In each division he disposes two frames or sashes, on which fine wire gauze is stretched for the purpose of intercepting the particles of powder in their course through the several divisions. Metallic zinc is preferred as the substance to operate upon, and a reverberatory furnace is employed to reduce the metal to vapor. The quantity of heavy oxide skimmed off the surface of the metal and from the walls of the retort, is drawn out by a rake into a passage which conducts it to a receiver in an inclosed chamber beneath the level of the sole of the furnace.

In the method patented by SCOTT, a clay retort of the usual form is used, imbedded in sand, potsherds, or pumicestone, and so placed in the furnace that the products of the combustion pass freely round it. The metallic zinc, which is directed to be used, is introduced through an inclined aperture, which is usually closed by the unmelted portion of the block of zinc. The air which oxidises the vapors of zinc issuing at the top of the retort, is admitted to an intermediate chamber, where both meet, and the product is carried by the current through a passage into a depositing chamber, the roof of which is constructed of zinced iron, and is capable of being converted by a raised ledge, into a shallow cistern, for the purpose of cooling the interior. The bottom of the chamber is divided into a number of funnel mouths, which, by attaching cloth or other material to the narrow part, lead the zinc-white at once into casks placed beneath to receive it.

HEVELIN'S patent, sealed in 1853, is based upon the same principles, only the apparatus is slightly modified, and a jet of steam is employed to effect the rapid oxidation of the metallic vapors as they rise from the retort, and also to aid in producing a certain amount of caloric expended in the operation. The jet of steam is introduced at the farther end of the retort, and passing over the metal, it is decomposed, the oxygen combining with the zinc, and the hydrogen passing off to be consumed in the air channel outside the distillatory apparatus.

TITTERTON prepares the zinc-white from the dross and dregs of the purifying pots of the zinc-smelting establishments by heating them alone, or mixed with a certain quantity of coke or charcoal, according to their composition. He employs two condensing chambers, the first intended for retaining oxide of cadmium, or other impurities, and the second for collecting the light white oxide of zinc. This patentee employs pressure, and a subsequent heating process, with the view of obtaining a denser compound, and therefore better suited for painting. *

ZINC-WHITE PAINT.—Like white lead, the oxide of zinc requires to be mixed with an oily vehicle, to be applied in painting. As oxide of zinc does not readily form a saponaceous compound with fats or oils like oxide of lead; the paint which is prepared with it and ordinary linseed oil, does not dry or harden for a long time. This peculiarity was at first one of the principal

drawbacks to the more general use of the zinc instead of the lead paint. Another of its defects is said to be its transparency, owing to which a layer of the zinc-white paint does not exhibit so much *body* or opacity as a similar one of white lead. Both these defects, which can be almost entirely overcome, are more than compensated by the permanency of the oxide of zinc as a pigment under all circumstances, and its comparative innocuousness both in the manufacture and the application; whereas the poisonous qualities of white lead constitute a fundamental objection to it. At first, manufacturers of zinc paint were led to the adoption of the practice of boiling the oil with a large quantity of litharge, for the purpose of causing it to be more siccative; but by this method the color of the paint is rendered liable to tarnish on exposure to sulphurous emanations. Instead of litharge, experiments have led to the choice of salts of zinc, such as the chloride and sulphate, a small per centage of which, on being mixed with the oil or oxide, confers upon the paint the property of readily hardening. The same result is obtained by employing an oil dried by boiling it with about five per cent. of peroxide of manganese, or even magnesia has been recommended, and is said to answer quite as well as the manganese; in either case a paint retaining its white color permanently is obtained.

Manufacturers classify the several qualities of the zinc-white into four kinds, namely, *snow white*, *zinc white*, *stone grey*, and *grey oxide*; the first two are employed where a pure unalterable white color is required; the third is used for a ground color for the walls of houses, iron painting, and the like; and the fourth is peculiarly adapted for the painting of ships and wood-work, and likewise for the ground of more expensive colors on stone or cement. Various shades may be given to paint of which zinc-white constitutes the basis, by grinding up with the oil, used as the vehicle, several metallic and other compounds of an unalterable nature in different proportions. Thus, an orange-yellow is obtained by using kermes—sulphide of antimony; a citron-yellow by employing chromate of zinc; a green by adding a mixture of chromate of zinc and a few per cents. of cobalt blue. In like manner oxides of iron and of manganese, ultramarine, lampblack, *et cetera*, communicate tints to the paint; all of which, owing to the absence of lead, are unaltered by atmospheric influences, sulphide of hydrogen, or other emanations.

Sometimes a very permanent and useful paint is prepared from the natural ores of zinc without subjecting them to any of the manufacturing processes already referred to for preparing the oxide of this metal. This is the case with the zinc-stone of Virginia in the United States, which has an average composition of—

Oxide of zinc,.....	25.00
Carbonate of magnesia,....	11.21
Alumina,.....	17.00
Silica,.....	28.00

This mineral constitutes a solid rock on the surface of the ground, and when pulverized and mixed with oil in proper proportions, forms on the surface to which it is applied a hard closely-adhering stone coating, impervious to water or fire. Its ordinary tint varies from a

light drab to dark brown. This paint is capable of receiving a high polish.

Oxide of zinc, or zinc-white, besides its application in painting, is valuable for paper-staining, card-enamelling, the bleaching of lace, the glazing of pottery and porcelain ware; and the lighter white portions are used for producing the down on artificial feathers.

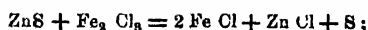
Analysis and Testing of Minerals and Compounds of Zinc.—A short summary of the method followed in the assaying of zinc ores has already been laid before the reader. It is almost needless to state that in consequence of the numerous sources of error almost inseparably connected with it, the process so described leads to no very accurate results. Hence in all cases where great precision is required, the liquid process must be adopted. Considerable difficulties are encountered in the analysis of zinc ores, and the compounds of this metal with others with which it is alloyed, in many valuable mixtures used in the arts—arising from the fact that sulphide of hydrogen does not separate members of the fifth and sixth group of bases, namely, mercury, silver, copper, cadmium, arsenic, *et cetera*, from zinc in acid solutions, as was for some time supposed; nor does potassa or ammonia, on the other hand, serve to isolate it from iron, nickel, and other members of the fourth group. These considerations have led to several processes for removing the cause of error, and conducting to more accurate determinations. As regards the action of sulphide of hydrogen, most of the analytical manuals to which the chemical student has access give details which are highly erroneous, and which, at best, serve only for qualitative rather than accurate quantitative determinations; for, in direct contradiction to what is commonly taught, sulphide of hydrogen does precipitate considerable portions of zinc in the form of sulphide from highly acid solutions. This fact was a few years ago very conclusively decided by Mr. C. CALVERT, whose research shows that the above agent cannot be employed in the manner detailed in the manuals to separate copper and other metals of its class from zinc. Again, potassa, which was for a long time supposed to be capable of parting zinc from iron, nickel, cobalt, and manganese, by dissolving the zinc in its excess, leaving the others permanently precipitated as sesqui- and protoxides, is now known to do so only partially, so that under almost every circumstance in which the precipitation is effected, more or less oxide of zinc is found in the separated oxides. Without going, therefore, into long details of the several processes recommended, the most trustworthy, and, at the same time, most expeditious method for the analysis of zinc ores and alloys will here be given.

The ore or alloy should be dissolved in nitric acid, and evaporated to dryness at a moderate heat, exercising the usual amount of care in the operation. If the subject be an alloy into which tin or antimony may have entered, these metals will be converted into insoluble binoxide in the case of tin, and into antimonious acid in case of antimony, particularly if the assay be treated with some fuming nitric acid, as it becomes nearly evaporated. After thorough desiccation the mass is treated with boiling water, filtered

and washed; the binoxide of tin or antimonious acid dried, burned, and weighed with due precaution, and the filtrate with the washings containing copper, cadmium, or other substances with the zinc, as the case may be, treated further. According to FLAJOLOT, the best process is to slightly acidify with hydrochloric acid, and boil the solution, and add hyposulphite of soda in excess to it whilst hot; sulphides of copper, cadmium, *et cetera*, are precipitated entirely free from zinc, by the decomposition of the hyposulphite. After thorough washing, the precipitated sulphides may be dissolved in acid, and the quantity of copper is determined by the processes already detailed under *Copper*; or if cadmium be present the solution may be treated with carbonate of ammonia in excess, and the vessel left exposed for some time, when carbonate of cadmium falls to the bottom, and the copper remains in the solution, to which it gives a deep violet or blue color. After the carbonate of cadmium is filtered off, washed with a solution of carbonate of ammonia and dried, it may be burned and weighed as oxide. The copper may be estimated with a standard solution of cyanide, or of monosulphide of potassium in the usual volumetric way. The zinc, iron, and nickel, with other matters capable of being separated by the reagent, may be thrown down from the solution with protosulphide of ammonium, the precipitate collected, washed, and dried at 212° till it ceases to lose weight; its entire weight is then noted, and the chief part introduced into a German glass tube on a platinum mattress or boat, where it may be heated to redness, whilst a current of sulphide of hydrogen is passed through the apparatus. When the heat has been sustained for a quarter of an hour, the lamp is removed, but the current of gas is still maintained till the tube and its contents are cooled. The platinum boat is then removed, and its contents emptied into a beaker, and treated with dilute hydrochloric acid, containing one part of strong acid in ten or twelve parts of water; sulphide of zinc is dissolved while the sulphides of cobalt, nickel, and iron remain intact. The quantity of the latter may be determined according to the processes which have been given respectively under *Cobalt*, *Iron*, and *Nickel*, and the zinc in the solution may be estimated by bringing the liquid to a boiling heat, and adding sparingly a solution of carbonate of soda, as long as a precipitate is formed, boiling the menstruum for some time to expel all carbonic acid, and then collecting the basic carbonate of zinc on a filter, washing with hot water, drying, igniting, and weighing the residue. During the ignition all the carbonic acid is expelled from the basic carbonate, so that only oxide of zinc remains, from the weight of which that of the metal may be calculated, since 40.0 parts of it contain 32.0 of zinc.

The oxide of zinc contained in ores of this metal may be determined by heating a weighed portion of them, finely ground, to redness for some time, and then treating the powder with a solution of carbonate of ammonia as long as anything is dissolved; the filtered liquid is next evaporated to dryness, and the residue heated to redness and weighed; this weight indicates the amount of oxide of zinc existing as oxide or carbonate in the ore. SCHWARZ, instead of evaporating

the ammoniacal solution of zinc, as in the foregoing, precipitates the metal as sulphide, either by passing sulphide of hydrogen through the liquid, or adding sulphide of ammonium to it. The sulphide of zinc is collected and washed with water, mixed with a little ammonia, and then introduced with the filter into a wide-mouthed flask, where it is treated with an acid solution of sesquichloride of iron, and slightly heated. Decomposition of the sulphide of zinc takes place in this case, and a reduction of a proportionate quantity of the iron salt to the state of protosalt, as explained by the formula—



that is, for every equivalent of sulphide of zinc one of the sesquichloride of iron is reduced to the state of protochloride, while sulphur is separated from the former, and chlorine from the iron salt assimilated. The liquid, as soon as it becomes clear by the deposition of the sulphur, is filtered off, and the quantity of iron in the state of protoxide estimated volumetrically by means of standard solutions of permanganate or of bichromate of potassa, and the amount of zinc deduced therefrom, since 56 parts of iron will represent 32.0 of zinc.

In the analysis of brasses, PELOUZE's volumetrical method may likewise be resorted to; and, according to CALVERT, with perfect accuracy. The brass is treated with an acid till perfect solution takes place, ammonia is added in excess, and a standard solution of monosulphide of potassium introduced from a burette, whilst a black precipitate forms in the liquid, and until a white one begins to appear. The quantity of copper being found from the volume of liquid used in the precipitation, that of the zinc may be taken as the difference.

Zinc is separated from nickel in many ways. If the alloy containing the two metals be dissolved in sulphuric acid, and the sulphates so produced be treated with acetate of baryta, a sulphate of baryta, with the corresponding acetates of nickel and zinc, will

be produced, with a little free acetic acid in proportion to the quantity of uncombined sulphuric acid which existed in the solution. Sulphide of hydrogen passed through this mixture, throws down the zinc as sulphide, leaving the nickel in solution. The precipitated sulphide of zinc and sulphate of baryta are filtered and washed, then treated with dilute nitric acid to dissolve the sulphide of zinc, and after removing this by filtration and washing from the insoluble baryta compound, the oxide is thrown down as a basic carbonate by treatment with a solution of carbonate of soda at a boiling temperature, then filtered, washed, and estimated as oxide, in the manner already detailed. The nickel can be thrown down as oxide, after expelling the sulphide of hydrogen with caustic soda or potassa, and its weight estimated in the usual way. WÖHLER separates the two metals by adding an excess of potassa to the solution containing them, then a sufficient quantity of hydrocyanic acid to dissolve the precipitate so formed. Double cyanides of the metals with potassium are thus produced, and which behave differently with protosulphide of potassium, the zinc salt only being decomposed by this reagent. By treating the solution, therefore, with protosulphide of potassium, sulphide of zinc separates completely, and may be removed and estimated in the usual way. The filtrate and washings should be evaporated to dryness with strong nitric acid to destroy the cyanogen compound, and the nickel determined by precipitating it with potassa or soda as already indicated.

STATISTICS.—Zinc was not an article of commerce previous to 1822, when it was imported in moderately large quantities, but only to be exported for the most part to India. The applications of the metal in the industry of the nation became gradually extended, till at present the home consumption averages about twenty thousand tons annually. The following table exhibits the imports and exports of the metal from 1823 to 1851; since that period the home consumption has been greatly on the increase, whilst the export remains about the same:—

Years.	Imports.	Exports to India.	Total Exports.	Home used.	Stock in January.	Highest and lowest prices
1823	5400	4536	4700	—	970	£22 to £23.
1824	9199	7185	8068	24	1140	£24 to £23.
1825	5556	4835	6112	171	413	£22 10s. to £41 10s.
1826	4839	7374	8330	22	924	£28 to £15 10s.
1827	5999	5535	6929	290	1262	£16 10s. to £14.
1828	4566	4806	4943	5.6	2447	£14 10s. to £11 10s.
1829	4230	3505	3964	684	2012	£12 to £9 7s. 6d.
1830	4422	3385	3479	843	1750	£9 10s. to £11.
1831	3821	2896	3134	941	1512	£11 5s. to £9 5s.
1832	3140	2044	2995	1093	1490	£10 10s. to £11.
1833	2800	1225	1883	1355	1020	£10 10s. to £12.
1834	2100	882	1419	1756	710	£12 to £14 10s.
1835	6500	2497	3943	2205	1350	£15 to £17.
1836	8600	1490	6269	2184	3110	£16 10s., £23 10s., and £19 10s.
1837	4380	1811	3200	2335	2750	£18 10s., £12, and £15.
1838	6265	528	1858	3596	2553	£15 10s. to £20.
1839	8910	1538	3391	4560	3650	£18 5s. to £21 15s.
1840	4965	26.7	4091	4181	1536	£20 to £23 10s.
1841	6509	990	1406	3665	2111	£23 10s. to £40.
1842	5500	1584	1900	2641	2800	£36 to £24
1843	10,173	3459	6445	4125	3750	£23 to £22.
1844	10,393	5826	5925	5388	4021	£22 5s. to £22 10s.
1845	12,903	2969	3084	7459	3296	£22 5s. to £22 15s.
1846	11,434	4875	4967	8450	6800	£22 to £19 10s.
1847	12,729	3901	3631	11,794	2250	£22 to £19 10s.
1848	13,525	2831	3773	9344	2000	£19 15s., £13, and £15.
1849	15,915	3927	5397	8726	2020	£15 to £16 5s.
1850	18,626	3121	4537	11,262	4000	£16 10s., £17 10s., £15, £16 10s.
1851	—	—	—	—	6827	£16 5s. to £15, May 1.

The duty on imported zinc from 1823 to 1825 was twenty-eight pounds ten shillings per ton; this was reduced in 1826 to fourteen pounds; in 1827 to twelve; in 1828 to ten, and in 1833 to 1842 to two pounds per ton. The duty levied in 1843 and 1844 was one shilling per ton, and since then all tax upon the imported metal was abolished. The average annual production from 1842 to 1848 was thirty-two thousand five hundred tons, of which—

Silesia made sixty-five per cent.,	or	21,000 tons.
Belgium made twenty	" or	6,500 tons.
Poland made eight	" or	4,000 tons.
Cracow made four	" or	
England made three	" or	1,000 tons.

Total,.....32,500 tons.

The smelting of zinc declined in England from 1850 till within the last few years that it has been a little more spirited in the several localities mentioned in the commencement of this article; during the same period the Continental establishments, more especially those of Belgium, have greatly enlarged their production. The quantity of zinc produced in the latter country in 1858 was twenty-five thousand six hundred and seventy tons.

The following represents the quantity of zinc smelted in the Prussian States from 1837 to 1848, inclusive:—

1837,...	21,546,600 lbs.	1843,...	36,047,200 lbs.
1838,...	20,983,200 lbs.	1844,...	41,314,100 lbs.
1839,...	21,636,600 lbs.	1845,...	43,861,200 lbs.
1840,...	20,879,800 lbs.	1846,...	43,961,000 lbs.
1841,...	19,977,900 lbs.	1847,...	44,221,800 lbs.
1842,...	27,612,600 lbs.	1848,...	39,873,600 lbs.

Of this quantity there were produced in the upper district:—

	1846.	1848.
In Silesia,.....	35,538,200 lbs.	36,193,100 lbs.
In Westphalia,	189,900 lbs.	75,000 lbs.
In Rhenish Prussia, ..	5,322,900 lbs.	3,605,500 lbs.

In France the quantity entered annually for home consumption to about 1848, amounted to eighteen or twenty thousand tons. Estimating the present consumption of that country at thirty thousand tons, that of England at twenty thousand tons, the other Continental nations and America at twenty-five thousand tons, the gross production would appear to average at present from seventy to seventy-five thousand tons annually, a quantity which approximates to the present yield of the several smelting works in operation.



SUPPLEMENTARY MATTER,

BY

PROFESSOR HORSFORD OF AMERICA.

ACETIC ACID.—Insert at foot of column 1, page 3, Vol. I.—The oxidation of the glycerin in fats also appears to be a source of acetic acid. By melting rancid Chinese vegetal tallow—palmitate and oleate of glycerin—in a flask, a strong smell of acetic acid is observed. REDTENBACHER found that an aqueous solution of glycerin is decomposed by the presence of ferments, and yields acetic and metacetic acids. By doubling the formula $C_6 H_8 O_6$ of glycerin, and subtracting 4 H, one obtains $C_{12} H_{12} O_{12}$, that is, three equivalents of the hydrated acetic acid. The oxidation of H_4 by the oxygen of the air, would produce the same result. From this it follows, that the acid reaction of rancid fats and oils, is for the greater part produced by the presence of acetic acid formed by the slow combustion of glycerin.—H.

Insert at foot of column 1, page 16.—A very neat apparatus for making small quantities of vinegar from alcohol, constructed by Dr. SITTALER, has been used in Germany for several years. It consists of a cylinder of glass, ten inches high and eight inches wide, filled up with coarsely-powdered charcoal. A glass cover, with a moderate aperture for the admission of air, closes the top of the cylinder, while a small cock is adapted near the bottom for the removal of the fluid. The apparatus must be kept at a temperature between 63° — 77° . Every evening six ounces of a mixture of one quart of alcohol, specific gravity 0.859, and eleven quarts water, are poured slowly and in a fine stream evenly over the charcoal, after which the cover is laid on. The following morning the corresponding quantity of vinegar may be drawn from the cock.—H.

Insert at foot of column 2, page 16.—It may here be interesting to mention an indirect mode of producing vinegar from wood. During the last few years, especially during the crisis caused by the ravages of the potato disease, serious experiments on a large scale have been instituted, with a view to substitute saw-dust and woody fibre in general for potatoes in the distillation of spirit. Many years ago, BRACONNOT found that saw-dust, cotton and flax fibres, *et cetera*, are converted into sugar by concentrated sulphuric acid. The sugar thus obtained is fermented in the usual manner, and the alcohol generated may be easily converted into acetic acid by any of the processes mentioned in the text. The cheapness of sulphuric acid, and the universal command of woody fibre, open a promising future to the new and ingenious process.—H.

Insert after PYROXYLIC SPIRIT or WOOD NAPHTHA,

page 25, column 2.—It may be well to remind the American readers, that the high duty on alcohol in England, renders the extraction of the pyroxylic spirit from wood a matter of great importance to the chemist. It is usual in England to burn wood spirit in lamps, and to use it generally as a substitute for alcohol, whenever its empyreumatic flavor is not objectionable, as tolerably pure wood spirit can be obtained cheaper than alcohol.

At page 27, middle of column 2, the reader is directed to use either sulphuric or hydrochloric acid for the purification of wood vinegar. It is far preferable to use hydrochloric acid for decomposing the lime-salt. Sulphuric acid forms with the lime gypsum, which converts the fluid to be distilled into a paste which it is very unpleasant to distil, as it boils irregularly and sometimes with explosions.—H.

The chloride of barium vinegar-test, mentioned at page 34, column 2, may perhaps be objected to, as calculated to mislead those unacquainted with chemical manipulations. In view of this, BÖRTGER has recommended a concentrated solution of chloride of calcium, for detecting the adulteration of acetic acid by sulphuric acid. He found that all kinds of vinegars, whether prepared from wine, alcohol, fruit, or beer, notwithstanding the small amount of sulphates which they contain, are perfectly indifferent to a concentrated solution of chloride of calcium. By adding to two drachms of vinegar a piece of crystallized chloride of calcium of the size of a small nut, and heating the whole to the boiling point, a precipitate of gypsum will fall down on cooling, if the liquor contains only one-thousandth part of sulphuric acid.—H.

In connection with the mordant made by decomposing alum by acetate of lead—see page 37, column 1—it may be stated that the preparation of acetate of alumina by double decomposition of sugar of lead and sulphate of alumina, gives rise to immense quantities of sulphate of lead, which is in many localities treated as a worthless refuse. By digesting it with a strong solution of carbonate of soda, it is converted into an inferior kind of white lead, which might be profitably disposed of, or else dissolved in acids for the preparation of lead salts.—H.

At page 41, foot of column 2, it is stated that the vinegar sold contains a small quantity of acetic ether, with the view, no doubt, of improving its taste and odor. It may be added, however, that an interesting formation of this compound was observed in a sour

and decomposed sugar-cane which had been sent from Andalusia to Paria. On splitting the cane open, a very strong smell of acetic acid and acetate of oxide of ethyle was perceptible. It is obvious that the presence of this compound, under the given circumstances, must be explained by the contemporaneous formation of acetic acid and alcohol from the sugar, both of which combine in the nascent state to form acetic ether.—H.

At page 42, column 1, it is stated that for commercial purposes, the protoacetate of iron is manufactured by introducing the materials into a large cast-iron boiler. By employing a copper kettle or boiler, the solution of the iron is effected more rapidly by galvanic action. As long as there is any iron left undissolved in the kettle, the copper will not be acted upon by the acid. A few drops of a solution of bichloride of platinum, added to six or eight ounces of concentrated hydrochloric acid used for dissolving tin, will induce a very violent action, and the tin will dissolve, requiring but little aid by heat. The same takes place when bichloride of platinum is added to the acetic acid for preparing protoacetate of iron.—H.

Insert, in connection with white acetate of lead, page 41, column 1.—It is a well-known fact among phytochemists, that sulphide of lead has a great affinity for coloring matters. Based on this observation, a German chemist proposed to decolor a colored solution of acetate of lead, by the addition of a small quantity of sulphide of potassium or sulphide of calcium. After boiling and filtering, the menstruum is clear and without hue.

ALCOHOL.—At page 50, top of column 1, it is stated that alcohol is never produced except by the vinous or alcoholic fermentation of particular substances. There is one exception to this rule. Pure olefiant gas is absorbed by agitation with concentrated sulphuric acid, with formation of sulphovinic acid; and by diluting the latter compound with water, and distilling the fluid, alcohol is obtained. This fact was discovered twenty-seven years ago by HENRY FLENNEL, though, singular to say, the discovery has lately been claimed by BERTHELOT.—H.

Insert at foot of column 1, page 107.—*Dunder* fulfils two important offices in the distillation of rum. In the first place, the large quantity of acetic acid contained in it, and formed at the expense of alcohol during fermentation of the wash, serves to decompose the sugarate of lime, contained in the generality of West India molasses in considerable quantities. It is for this reason that *dunder* increases the yield of rum. Sugarate of lime does not ferment, and when present in considerable quantity, actually opposes the fermentation of the wash; so that without *dunder*, fermentation would proceed so sluggishly that most of the alcohol would be converted into vinegar. This occurrence might be avoided by adding the diluted molasses containing sugarate of lime, to its own bulk of strongly fermenting wash. The carbonic acid of the fermenting liquor would then perform the office of the acetic acid of the *dunder*, by precipitating the lime as carbonate of lime and liberating the sugar. The American Editor disproved the idea that *dunder* is connected with the fine flavor of rum, by two experiments. In

one trial, molasses—from which all the lime was precipitated by sulphurous acid—and water only were used. The resulting rum was a very fine-flavored spirit, and the yield was perceptibly greater than from molasses not thus treated, though from similar cane. Another trial was made by partially filling the rectifying vessels or retorts, as they are called in Jamaica—they are like the wash-heater, as prepared R, Fig 78, and connected with the still in the same manner—with *dunder*, with a view to increase the flavor of the rum, as might be expected if the flavor proceeded from that source. The rum, however, thus obtained had the disagreeable flavor of the *dunder* totally different from that of *Old Jamaica*. The flavor of the rum appears to depend entirely on the presence of a fusel-oil, the formation of which is immediately dependent on the proportion of the surface of the wash exposed to the air during fermentation, to its entire volume. It is well known that two contiguous sugar plantations will produce very different qualities of rum, though operating in the same identical way. But it has been observed that in such cases the size and the exposed surface of their fermenting vats were different, or if not, the stills were of different capacity. The protracted boiling of the wash in very large and deep stills, injures the flavor by increasing the empyreumatic products. From the above observation it would follow, that the origin of the genuine flavor is intimately connected with the more or less complete oxidation of the molasses ferment induced by the greater or smaller surface of the wash—compared with the bulk—exposed to the air. Large cubical cisterns, holding one thousand and more gallons, yield an inferior rum, as compared with smaller vats having a larger exposed surface. Similar observations made by LIENG with regard to Rhenish wine appear to confirm this opinion.

The second office fulfilled by *dunder*—an office of some importance for the more rapid development of fermentation—is by its richness in ferment. The colonial distiller does not employ any yeast for inducing fermentation of his wash; he is consequently obliged to work upon more dilute solutions of molasses and skimmings—collectively called *sweets*—than are used by his continental competitors. Any, even the slightest source of ferment, must therefore be welcome for his purpose. *Dunder* is such a source. Ferments, it is well known, are destroyed by boiling-heat of water, and recent *dunder* is in that respect perfectly inert; but by exposure to air in shallow tanks, an oxidation and regeneration of the *killed* ferment takes place, and it is to this circumstance that a part of the favorable action of *dunder* must be ascribed.

Without the assistance of *dunder* a more rapid fermentation of the wash may be obtained by converting the cane-sugar contained in molasses into grape-sugar, by treatment with a small quantity of acid, which is subsequently neutralized. It has been stated that less ferment is required for converting grape-sugar into alcohol than cane-sugar, a fact which will render it less miraculous to hear that some plantations manufacture a superior rum while their sugar is nearly as dark as coal-tar. Molasses from such sugar contain chiefly grape-sugar. Allusion has already been made to the

fine flavor of rum made from molasses which were obtained by boiling sugar with an excess of bisulphite of lime.

Cleanliness in the operation of the distilling is a standard admonition of the theoretical world, woefully disregarded by the practical. In fact, it appears that a premium is offered to malpractice in this instance, as many of the most detestable colonial distilleries turn out very creditable produce. Whether the exception proves the rule in this case, must be left undecided. However, if cleanliness is not absolutely required for improving the flavor of the spirit, it would be a charity to the still-house bookkeeper, who is condemned to pass part of his lifetime in these disgusting dungeons.—II.

Page 117, column 2, *Alcoholometry*.—To the analytical chemist it happens sometimes that only small quantities of the alcoholic fluids are at his command. In such cases it is almost impossible to obtain a correct result, by determining the specific gravity of the few drops of alcohol obtained by distillation. It is safer to subject the alcohol obtained to an organic analysis by combustion with oxide of copper, and calculate the quantity of absolute alcohol from the resulting carbonic acid and water. This is of course only applicable when the alcohol does not contain other volatile bodies, like etheral oils, *et cetera*.

ARSENIC.—At the top of column 2, page 215, Vol. I., insert—In the presence of oxide of iron, minute quantities of arsenic cannot be detected by the blow-pipe. In that case, the oxide of iron must be treated with a boiling solution of potash, which is afterwards neutralized by sulphuric acid, and tested in MARSH'S apparatus.

In same page and column the reader is directed to drop a few fragments of pure zinc into MARSH'S tube-apparatus. It deserves to be remarked, however, that pure zinc, especially when in large pieces, frequently dissolves so slowly in dilute sulphuric acid, that it is impossible to obtain a steady hydrogen flame. The addition of a drop of bichloride of platinum, or of a small quantity of platinum black, will remedy this difficulty. If the fluid to be tested contains any considerable quantity of arsenic acid, this alone is sufficient to produce a violent reaction of the acid on the zinc.—H.

BALSAM.—Vol. I., column 1, page 223.—*Canada Balsam*.—This balsam is mostly used by optical instrument-makers for cementing together the different parts of achromatic lenses, NICOL'S prisms, *et cetera*. It may be here added that Japan varnish is a balsam derived from *Rhus vernix*, and serves to impart a brilliant lustre to metallic and other objects, hence denominated *japanned articles*.

BEER.—In connection with the analysis of beer, pages 281–284, the following may be given:—

ANALYSIS OF VARIOUS KINDS OF CELEBRATED BEER.

	Water in 100.	Extractive matter.	Alcohol.	Carbonic acid.	Analyst.
Barclay's ale,....	86.98	6.02	6.90	0.15	Raiser.
Burton ale,.....	79.62	14.50	5.88	0.04	Hoffmann.
Pale ale,.....	89.85	4.50	5.65	0.07	"
Barclay's porter, ..	88.74	5.98	6.10	0.18	Raiser.
London porter, ..	86.28	6.80	6.91	—	Balling.
Bavarian ale,....	90.96	4.70	4.34	—	"
London ale,.....	76.03	15.88	8.08	—	"

BENZOL.—Insert at foot of column 1, page 286, Vol. I.—The rectified volatile oil from coal-tar, distilling between 212°–320°, and consisting mostly of benzol, toluol, and cumol, has been strongly recommended for oil paint in the place of oil of turpentine. It has the advantage of evaporating rapidly, whereby apartments painted with oil paint are rendered much sooner inhabitable.

A curious and interesting application has been made of benzol by the well-known photographer, M. DE ST. VICTOR, based upon the property of this fluid, to be lighter than water and insoluble in it, and to be kindled with the greatest facility by a small flame in contact with air even at low temperatures. He found that benzol, to which have been added a few pieces of potassium or phosphide of calcium, readily inflames when thrown on water. An experiment was made on the Seine in Paris, in which three hundred grammes of benzol were inclosed in a glass-bottle, with half a gramme of potassium. The bottle was floated down the river, and suddenly broken. The potassium ignited and set fire to the benzol which burned with an immense flame, which, though smoky, had great intensity, and lasted fully a minute in spite of a strong breeze.

A repetition of this experiment in the fountain of the garden of the Palais Royal gave the same result. In spite of a heavy rain, the flame lasted over a minute.

M. DE ST. VICTOR proposes a mixture of benzol with sulphide of carbon in which phosphorus has been dissolved, as a close imitation of the famous liquid Greek fire.—II.

BISMUTH.—Insert at foot of column 1, page 288.—An alloy for galvanoplastic moulds is prepared by fusing together eight parts of bismuth, eight parts lead, three parts tin. This mixture melts at 225°. For preparing the mould, the alloy is fused and poured into a paste-board boat of about one quarter inch depth; it is then stirred with a heated iron-wire until its surface is perfectly even and bright. As soon as it has acquired a pasty consistence, the medal to be moulded is slightly heated, and immediately pressed on the alloy, and kept under pressure until cool.—Böttger.

BLEACHING.—Insert at foot of column 1, page 315, Vol. I.—Mr. L. BENNER, chemist of KÖCHLIN'S print-works at Darnetal, near Rouen, has lately recommended the use of sugarate of lime—sugar-lime—in place of caustic lime for bleaching of cotton fabrics. He describes his process as follows:—For one scouring operation, two hundred pieces of fourteen pounds each are worked upon, and the operation is performed in large kiers, heated on the open fire, and under a pressure of about twenty-two pounds to the inch. As soon as the pieces are singed, they are passed through a washing-machine—similar in principle to ROBINSON'S—in order to moisten them sufficiently to prevent any danger of combustion. After this they are wound by a mechanism into a tub in which they are spread in large folds. During the latter operation a milk of lime, containing forty pounds burnt lime, runs on the pieces in such proportion that the forty pounds of lime will be used up by the two hundred pieces. From this liming tub the pieces are mechanically transferred to the bucking kier, in which

they are arranged in separate layers. After covering and fixing the fabrics by wooden cross-bars, as much water is added as will cover the pieces to the height of twelve inches, after which the sugar-lime is added. The latter is prepared by mixing in a tub thirty pounds burnt lime with seventy-two pounds boiling water; after slaking, thirty-six pounds more of hot water are added to dilute the lime-paste. To this milk of lime are added fifteen pounds of molasses, previously diluted with thirty-six pounds of hot water. The whole is well stirred and thrown into the bucking kier, whereupon the cover is fastened, and the charge kept boiling for eight hours. The fire must, however, be increased very gradually, so that the operation is finished in about ten hours.

This operation ended, the pieces are taken out, passed twice through the washing-machine, and brought back again into the bucking kier. The pieces are folded up as before, covered with twelve inches of water, which is mixed with the sugar-lime prepared from thirty pounds of burnt lime and ten pounds of molasses. The charge is again boiled during eight hours; the pieces are then removed, passed twice through the washing-machine, and steeped in hydrochloric acid of specific gravity $1.010 = 2^\circ$ Twaddell during four hours. They then undergo two washings—are brought back to the bucking kier a third time to be finished for bleaching by a single soda-ley.

The sugar-lime being readily soluble in water, and acting in all respects like free lime, has, of course, the great advantage of intimate contact with all the particles of grease and resinous substances which are fixed on the fibre; while the caustic lime, in consequence of its restricted solubility, especially in boiling water, is less complete in its saponifying functions.

The bleaching process is carried out as follows:—After packing the pieces in the bucking kier, and covering them with twelve inches of water, a solution of sixty pounds of soda-crystals is added, the cover of the kier fastened, and the charge boiled for three hours. The fire is then withdrawn, the steam allowed to escape, and the cover removed. The soda liquor is drawn off and replaced by cold water, to which a resin-soap, prepared of one hundred pounds of soda ash and one hundred pounds of resin, is added. The cover is replaced, and the charge boiled for twelve hours, after which the soap-ley is withdrawn, the kier filled up with cold water as before, a solution of sixty pounds of soda crystals added, and the charge again boiled for three hours. The pieces are now removed to undergo the washing process twice, before being wound into the bleaching solution of chloroxide of calcium, where they remain a few hours; hence they pass through water, then receive a scouring in weak hydrochloric acid, and pass twice through the washing-machine.

Pieces which have not been treated with solution of chloroxide of calcium, are equally as well adapted for dyeing purposes; and the treatment with bleaching liquor may therefore be dispensed with for the greater part of the pieces.

The first scouring with soda crystals is intended to remove traces of acid, and most of the resinous matter, to prepare and aid the action of the resin-soap.

The second boiling with soda crystals is to remove

the remainder of resinous substances, and also to free the fibre from adhering resin-soap.

This method of giving two scourings with sugar-lime offers the great advantage over those methods, where only one scouring with a comparatively strong ley of lime is employed, of weakening the fibre in a less degree.

ANTICHLORINE.—The property of cotton and other woody fibre to condense gases and colors on its surface by a peculiar physical attraction, is well understood. This action, which it has in common with all solid bodies, is so powerful in some instances, that it may even counteract chemical attraction. Cotton and other vegetal fibre which has undergone the bleaching process by chlorine, for instance, has the property of powerfully retaining some chlorine gas. The difficulty of removing this effectually from the bleached fibre is almost insurmountable, requiring a great sacrifice of time, when rapidity is so essential, besides large volumes of water and increased machinery. Now, in order to insure the proper rapidity of the manipulations, either an appreciable amount of chlorine must be left in the bleached fabric or paper-pulp, or else this chlorine must be removed by substances bringing superior chemical affinity into play.

The expedient of only partially removing the chlorine from cotton cloth is certainly in favor of the manufacturer, to the evident disadvantage of the consumer. Chlorine acts gradually on the fibre; it combines with its hydrogen and disorganizes it, renders it brittle, aided by the hydrochloric acid formed. The same is the case with paper-pulp. The action of chlorine left in the bleached pulp is particularly illustrated by the paper manufactured in France soon after the introduction of chloroxide of calcium into the paper-mills. The paper, on running over the hot drying rollers of the machine, becomes brittle; the books printed on it gradually become full of brown spots, and acquire a uniform brownish tint. Every bookseller is acquainted with the inferiority of the modern printing paper in this respect. This deterioration must be entirely ascribed to the action of free chlorine, adhering to the fibre. It is not the paper alone that suffers; the type, too, with which it comes in contact, is affected in proportion to the amount of chlorine left in the paper. It is well to direct the attention of paper-makers and printers to this point, and so furnish them with a ready explanation of the rapid deterioration of the paper and type, and to draw their attention to those chemical agents which may be employed with advantage for counteracting these evils. Agents of this description have been introduced to the public under the general designation of *antichlorine*.

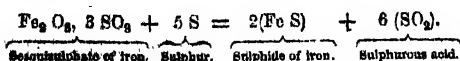
Carbonate of soda or ammonia was first proposed as an antidote for chlorine; but though the latter gas decomposes soda or ammonia in concentrated solutions, the effect in very dilute fluids is very insignificant, and requires the aid of heat. Sulphide of calcium was next introduced; but its property of being decomposed by carbonic acid, with evolution of the fetid sulphide of hydrogen gas, and the black precipitate which it produces with any salt of iron or copper which may be present in the pulp by accident, preclude the use of

this salt. Protochloride of tin—tin salt—and a mixture of protosulphate of iron and salt, have the disadvantage of introducing metallic salts into the pulp, which are about as objectionable as chlorine itself. Hyposulphite of soda is somewhat expensive, and precipitates sulphur when brought in contact with chlorine or hydrochloric acid, the sulphur giving a yellowish tint to the paper. Recently a patent was taken out by ROTH and LEA of Philadelphia, for the use of a solution of sulphite of soda as an antichlorine. Sulphurous acid and its salts are indisputably the most economical, besides being the most efficient chemical compounds for removing free chlorine. Sulphurous acid alone, however, cannot be employed for the purpose in question, on account of being converted by chlorine into sulphuric acid, which has a detrimental action on woody fibre. The sulphite of soda answers, therefore, all practical purposes, as far as its chemical action is concerned; it is, however, still liable to the objection of difficult transportation in its fluid state, in which it must be sold for reasons of economy, entailing additional expense on the consumer for water-tight casks and freight of a valueless substance—water. These considerations, which oppose a more general application of the sulphite of soda, have induced Professor HORSFORD to make the use of the cheap sulphite of lime or *antichloride of lime*, the subject of a patent for England and America.

It may appear on first consideration that neutral sulphite of lime, which is very little soluble in water, could have but little effect on the chlorine combined with the fibre; but the fact that hydrochloric acid dissolves neutral sulphite of lime with formation of soluble bisulphite of lime, will readily explain its action. Now hydrochloric acid is invariably generated whenever chlorine gas acts as a decoloring agent on organic substances.

It is the hydrochloric acid thus generated which dissolves the neutral sulphite of lime. Contact with chlorine converts the sulphite into sulphate of lime, which goes to increase the weight of the paper, and practically saves to the manufacturer nearly or quite the whole cost of the sulphite of lime. The article is prepared by agitating milk of lime by means of revolving paddles in a long close box, with fumes of burning sulphur, until the reaction is neutral or acid. It is then drained and air-dried, and packed in casks for transportation.

In connection with the formula given at page 324, column 2, it deserves to be stated that, instead of taking the protosulphate of iron— FeOSO_3 —for the preparation of sulphurous acid, it is more advantageous to employ the *sesquisulphate of iron*— $\text{Fe}_2\text{O}_3, 3\text{SO}_3$ —which is obtained by *roasting* green vitriol in the air, and then adding to it half as much more sulphuric acid as it already contains, and evaporating the resulting pasty mass to dryness. One hundred and ninety-eight parts of the dry sesquisulphate of iron are now mixed with eighty parts of sulphur, and heated, whereby one hundred and ninety-two parts of dry sulphurous acid gas are obtained:—



while one hundred and ninety-eight parts of the *protosulphate of iron* will only yield one hundred and sixty-nine parts of sulphurous acid.—H.

BLEACHING POWDER.—At page 328, immediately preceding the formula at foot of column 1, it is stated that the chlorine employed in the experiments was prepared by adding hydrochloric acid to chlorate of potassa. But BÖTTGER found that the gas thus obtained contained ClO_2 . It is to be presumed that the mixed gases were passed through sufficient water, and at a rate sufficiently slow to permit the entire absorption of the ClO_2 .—II.

At page 329 a description is given of FRESenius and WILL's method for testing the quality of manganese ore. A modification of this method, more simple, and still equally satisfactory for practical purposes, has been proposed by MOHR. It is executed in the following manner:—Three grammes of the finely-powdered and dried manganese ore are mixed in a small glass flask with a little water, and enough sulphuric acid to render the whole mass perfectly fluid. This flask and a porcelain capsule containing about nine grammes of crystallized oxalic acid, are now placed in one scale of the balance, and brought into equilibrium by a basin of sand or small shot. The oxalic acid is now thrown into the flask, where it immediately begins to reduce the binoxide of manganese under evolution of carbonic acid. To accelerate this decomposition, it is good to give the flask a circular horizontal motion, until the evolution of the carbonic acid has ceased, and the mass from black, which it was, has become light-colored. The empty porcelain capsule and the glass flask are now again placed on the balance, and so much weight placed into the capsule as to restore the equilibrium. The weight required to effect this is equal to the weight of a binoxide of manganese in the ore, because one equivalent of binoxide of manganese = 44, when treated with oxalic and sulphuric acids, cause the evolution of two equivalents of carbonic acid = 44; one part by weight of binoxide of manganese is therefore indicated by one part of carbonic acid.

Now, as three grammes of ore have been employed for the above experiment, it follows that the amount of carbonic acid lost, divided by three, indicates the amount of binoxide of manganese in one gramme of the ore; and by multiplying the latter number with one hundred, the per centage of the binoxide is obtained. The error produced by the loss of water in this method does not signify for most practical purposes, but may be remedied by closing the flask with a cork in which a glass tube filled with dry chloride of calcium is fastened. In this case, however, the carbonic acid contained in the flask when the experiment is finished must be removed by suction.—H.

BONE BLACK.—At page 336, eleventh line of first column, it is stated that solutions of sugar are better deprived of their color when alkaline than when acid. This, however, only applies to an alkalinity of sugar sirup produced by *lime*.

Some interesting reflections are suggested by the remark which follows in the same column with reference to the decoloring power of carbon, and M. BUSSY'S

experiment, showing that the reaction is strongly influenced by ordinary chemical forces, instead of being purely mechanical. As the whole universe, with all its diversified phenomena, derives its origin from one *primum movens*, and as all the phenomena connected with matter can therefore only be functions of this creative unit, one may, *a priori*, expect that which is actually observed, namely, the gradual transition and intimate connection of varied effects and causes. Where does inorganic nature cease and life commence? Where stops the action of light, and where does heat begin? Why does magnetism induce electricity? Where do the physical forces—cohesion, repulsion, heat, electropolarity, light and contact force, find a landmark which separates them from what are denominated chemical forces? Every effect must have a cause, and every distinct effect a distinct cause; but it is the defect of the human mind to be slow in distinguishing apparent from real differences. Before NEWTON it would have been undoubtedly considered good logic to conclude, that the force which made the apple *fall* was different from that which kept the earth *steady*. Thus it comes that all definitions of isolated systems fail, and undergo continual amputation and restoration with every progress of science—now hobbling on one hobbled leg, now on another—showing that nature abhors, if not the vacuum, at least systems and definitions; and it teaches that there is no gap in its mechanism, no wheel or spring wanting in its clock-work; in fine, there is no interruption in its development from a single cause or *animus* to its utmost complicity, which is observed in the perfection of organic existence. A disruption in the continuity of effects in the economy of nature would be equal to the interruption of an electric wire between two telegraph stations; because in that case the intelligent cause on one station could no more produce an intelligent effect on the other, in consequence of an apparently insignificant accident. The forces as connected with the phenomena of matter, are in the same predicament. There can be no *real* difference in the so-called forces, because such a difference would constitute a *real* gap; it would stamp the force as an individual, producing an individual effect, so that all the infinitely different effects observed must be ascribed to infinitely different forces.

The attraction of coloring matter by charcoal is denominated mechanical, while the attraction of sulphuric acid by baryta is classed with chemical effects. But animal charcoal does not only attract coloring matter; it also decomposes metallic salts, and fixes their base by that same power of retention. Now it is known that chemical combinations and decompositions are produced by differences in intensity of one only chemical attractive force called affinity. It is evident that the same force is inherent in animal charcoal. This view is corroborated by the fact that animal charcoal absorbs different compounds in different but determined quantities. NIEPCE has shown that iodine and chlorine gas are condensed by the inked portion of printed paper, while the white portion of the paper does not retain any of the gases. Charcoal absorbs heat and light most readily. It condenses

electricity on its surface, and thereby acts as a non-conductor, the same as glass, which is only an isolator in consequence of its great attraction for electricity. Metallic charcoal loses, with its power of attracting colors and gases, also the power of attracting electricity, which latter now passes through without hindrance, as through other conductors. Ordinary charcoal condenses gases, and frequently causes chemical combinations. This substance, then, shows the gradual development of chemical effects by physical forces. The effect of animal charcoal depends entirely upon its porosity and the extent of its carbonaceous surface, and is directly proportional to it; and it may therefore be presumed that if the surface of charcoal could be indefinitely increased by solution in water, it would produce all the powerful chemical phenomena of cyanogen or ozone.

If one moves on a step further, binocide of tin presents itself, a substance already more pronounced in its chemical character than charcoal. Still it is inclined to combine equally as well with bases as with acids, showing a transition character. Now, if pumice be soaked in a solution of bichloride of tin, and then dipped into a solution of carbonate of soda, the pumice acquires all the properties of animal charcoal. Very porous pumice, finely-divided silica, cotton fibre—all these show signs of chemical power depending on their extent of surface; and it may well be supposed that this chemical power would be more prominent, could they be obtained in the fluid state. Silicic acid, which is as inert as charcoal at the ordinary temperature, drives out the powerful sulphuric acid from its combinations at a temperature nearer its own melting point.

Another phenomenon is also connected with the action of animal charcoal, namely, that of endosmosis. It has been shown, as subsequently stated in the text, that a colored sugar solution containing, besides water, some salts, does not pass unchanged through animal charcoal. Pure water is the first to pass through, then comes water with salts, then sugar, and lastly, the color. From this one concludes that animal charcoal has the greatest affinity for coloring matter, less for sugar solution—because the latter is replaced by the former—still less for salt solution, and least of all for water. Could, therefore, a thin diaphragm be constructed of animal charcoal, one would observe the endosmosis to take place from a salt solution into water, and from a solution of sugar into salt, and from a solution of coloring matter into water, salt, and sugar; that is, of such tinctorial matter as has the greater affinity for animal charcoal. Thus a certain molecular attraction in animal charcoal may produce effects ascribed to a multiplicity of forces, as mechanical force—adhesion, endosmotic force, catalytic force; and chemical force—affinity. Would it not be more rational to consider all these as mere functions of the same molecular tendency the intensity of which alone gives rise to variable effects, the same as is observed in sound, electricity, and light?—H.

CORRENWINDER assumes that the decoloring effect of animal charcoal is correlative to its absorbing power for lime; and on this supposition he bases the following method for determining the commercial value of bone

black:—A solution of sugarate of lime is prepared, containing, say, twenty grammes of lime in one thousand cubic centimetres fluid, which are neutralized by one thousand cubic centimetres of a standard solution of sulphuric acid, so that fifty cubic centimetres of the acid solution indicate one gramme lime.

The samples of the bone black are now rendered of a uniform condition, by passing them separately through the same sieve, after having removed the fine dust by a paper fan. Fifty grammes of each sample are placed each in a glass flask. In each glass flask one hundred cubic centimetres of the solution of sugarate of lime are added to the bone black, and the whole allowed to digest for an hour. After this the fluid of each flask is filtered separately, and fifty cubic centimetres of the filtrate liquor are tested for the amount of lime with the standard solution of sulphuric acid. The more lime there is absorbed by the bone black, the less sulphuric acid will be required to neutralize the filtered liquor; and that liquor which requires least acid for neutralization, must have been in contact with the most valuable sample of bone black, so that the value of the animal charcoal increases directly as the amount of standard acid required for neutralization decreases.—II.

BORACIC ACID.—At page 342, it is stated that boracic acid scarcely reddens* vegetal blues, and renders turmeric brown, like an alkali. This reaction affords an easy means of detecting boracic acid in its combinations, by adding to it a little hydrochloric acid; after which dip into the fluid a piece of turmeric paper, and then dry it. If a trace of the acid was present, the paper will have a brown stain after drying.—II.

BRFAD.—Insert at foot of column 1, page 377, Vol. I.—The frequent failure of the grain crops, and the scarcity of grain induced by some other accidental causes, has drawn the attention of chemists to the process of bread-baking, either with a view to discover some substitute for wheat flour, or else to find the means for rendering the whole of the nutritive principles of the cereals available for consumption. The latter direction has already furnished valuable results. It is known that the bran separated from flour contains a comparatively large proportion of nitrogenized substance, namely, that constituent of the flour which contributes most to nutrition. Until quite recently the bran was lost to the nutrition of man. Now, however, it has been shown that this nitrogenized substance may be extracted from the bran without much trouble and expense, so as to obtain the whole of its valuable matter. This process, recommended by a number of chemists, was ultimately patented in France by a Mrs. DURUT. The manipulation is carried out in the following manner:—Bran is mixed up with boiling water in a kettle over a moderate fire, so that the mixture has a semifluid consistency. The mixture is now heated carefully until the bran loses its raw smell—not till it is cooked; it is then transferred into bags and pressed. The pressed cake is treated once more in the same manner, mixing it with water, allowing to boil for a short time, and pressing. The fluid obtained by this second operation is used, instead of pure water, for a fresh portion of bran. By the first pressing a sirupy

juice is obtained, completely saturated with gluten, and which is destined to replace the pure water in the process of bread-baking; thus gaining for the bread a large proportion of valuable nutriment entirely lost before. The economy of this process is thus stated:—A bag of flour of the average weight of three hundred and twelve pounds, made into bread with water in the usual manner, yields on an average one hundred and four loaves of four pounds each. A bag of flour of the same weight, made into bread with the extract of bran, yields one hundred and thirty loaves of four pounds each, or a clear gain of twenty-six loaves over the old process. Twenty-five per cent. increase in the yield of bread from the same amount of flour is a fact the importance of which cannot easily be exaggerated.

BROMINE.—The process detailed at pages 393, 394, for the separation of bromine and chlorine, may with advantage be modified in the following manner:—Precipitate the solution containing chlorine and bromine with nitrate of silver; wash, dry, and heat the precipitate to a state of semi-fusion in a weighed porcelain capsule. Weigh the capsule with the silver precipitate, then reduce the latter with the aid of zinc and sulphuric acid in excess. Wash out the reduced silver, ignite, and weigh it. If one supposes the weight of the chloride and bromide of silver to be a , and that of the metallic silver obtained from it by reduction with zinc to be b , and the amount of chlorine to be x , the amount of bromine will be $a - b - x = y$. From this we conclude:—

$$\frac{107.97x}{35.46} + \frac{107.97y}{79.97} = c,$$

from which is deduced:

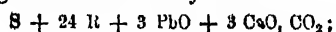
$$x = 1.38674C - 0.79667a$$

That is, multiply the weight of the reduced silver by 1.38674, and deduct from the result the product obtained by multiplying the weight of the chloride and bromide of silver with 0.79667, and the result will be the amount of chlorine in the mixture. By subtracting the weight of the chlorine plus that of metallic silver from the weight of the chloride and bromide of silver, the amount of bromine is obtained.—II.

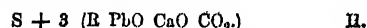
CANDLE.—Read, in connection with the processes described at pages 430, 431:—The operations of saponification of the fat, and decomposition of the lime-soap by sulphuric acid, have been hitherto effected in open vessels, under the ordinary pressure of the atmosphere. An improvement on this plan has been recently proposed by M. DELAPCHIER, of Besançon, who substitutes close vessels in order to saponify the fat. Wash and decompose the lime-soap under a pressure of about twenty-two pounds to the square inch, by which the operations are considerably facilitated, and their duration shortened. The products by this process are said to be superior to those obtained in open vessels, and a considerable economy of fluid is effected. The apparatus consists essentially of a horizontal boiler, with a man-hole and two safety valves at the top. The heat is furnished by a large steam-pipe, running in a depression along the bottom of the boiler. The

pipe is perforated with numerous holes to distribute the heat more uniformly. A horizontal iron shaft, which passes through stuffing boxes in the heads of the boiler, carries an agitator, the transversal ribs of which nearly touch the circumference of the boiler. A large pulley at one end of the shaft receives its motion from a suitable motor. The materials are charged through the man-hole, and at the end of the operation withdrawn by a large valve at the bottom of the boiler.—H.

CAOUTCHOUC.—The qualities of sulphurized caoutchouc are described in column 2, page 448, vol. 1:—Allowing the chemical composition of caoutchouc to be $C_8 H_7$, the formula of the best vulcanized rubber car-springs is found to be very near—



R signifying one equivalent of rubber= $C_8 H_7$. If rubber was represented by $C_{64} H_{56}$ —or eight times its present equivalent—the vulcanized car-springs would have the compact formula:—



CIDER.—At page 475, middle of column 2, it is stated that in warm seasons it is still a desideratum to discover some means of checking a too rapid fermentation of cider. The process for the prevention of fermentation in saccharine solutions, denominated *mutisme* by the French, may be very easily applied for effecting this purpose. By adding to fermenting powder from one six hundredth to one thousandth of neutral sulphite of lime, or of bisulphite of soda, the fermentation may be reduced to a minimum, or entirely checked.

END OF VOLUME TWO.

